Appendix C. System Design Analysis and Trade Studies

The following analysis and/or trade studies are included in this appendix:

Appendix C.1 LPS Architecture Alternatives

C.1.1 Objective

The objective of this study is to evaluate alternate architectures for the LPS. Specifically, this study reviews the advantages and disadvantages of centralized and distributed architecture alternatives for LPS data processing.

C.1.2 Centralized Architecture Alternatives

The centralized option with one processor is not considered a feasible solution since there is no single processor hardware available to perform the necessary functions at the throughput rates required by the LPS. Therefore, a multi-processor hardware solution is needed.

The centralized option with multiple processors can be implemented in two different ways. Figure C.1-1, shows the configuration of a single string LPS with multi-processor capability for processing all 4 data inputs. The cost of providing redundancy (e.g. a second string) to achieve a higher system availability is equal to the cost of the whole LPS system. Also, with this configuration, a single failure affects all four LPS data inputs.

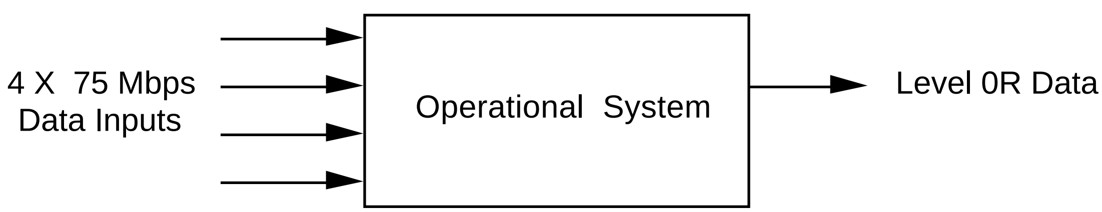


Figure C.1-1: Fully Centralized Processing Architecture (Single String)

Figure C.1-2 shows the configuration of a dual string LPS with multi-processor capability for processing all 4 data inputs. Each LPS string processes 2 data inputs. The cost of providing redundancy (e.g. a third) to achieve a higher system availability is equal to half the cost of the whole LPS system. A single failure in this configuration affects two of the four LPS data inputs.

The centralized options have the advantage of being able to correlate output data from among two or more data inputs. This is possible since different data inputs are processed within the same processing hardware/string.

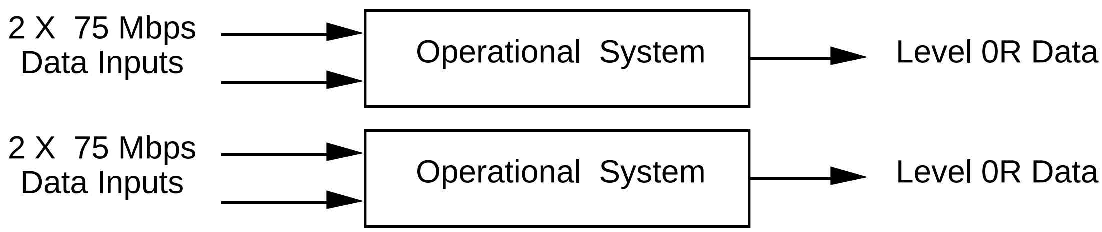


Figure C.1-2: Partially Centralized Processing Architecture (Dual Strings)

C.1.3 Distributed Architecture Alternatives

The distributed architecture utilizes multi-processors hardware strings to build a single Landsat 7 Processing System (LPS). The fully distributed configuration, shown in Figure C.1-3, consists of 4 independent hardware strings each responsible for capturing and processing a single data input. Single failures affect only one data input thereby allowing the other three data inputs to process normally. Also, the cost needed to provide redundancy (e.g. a fifth string) for higher system availability is between 50 and 75 percent less than the fully centralized option. Additional cost savings are obtained through lower lines of code generated since the software does not need to coordinate all four data inputs as is needed in the centralized option. Another advantage with this option is that contention for system resources during system development, test, integration and delivery is minimized. The major trade-off between the two options is cost versus data input correlation. A system engineering trade was made to realize the cost savings and provide data input correlation at the operational level.

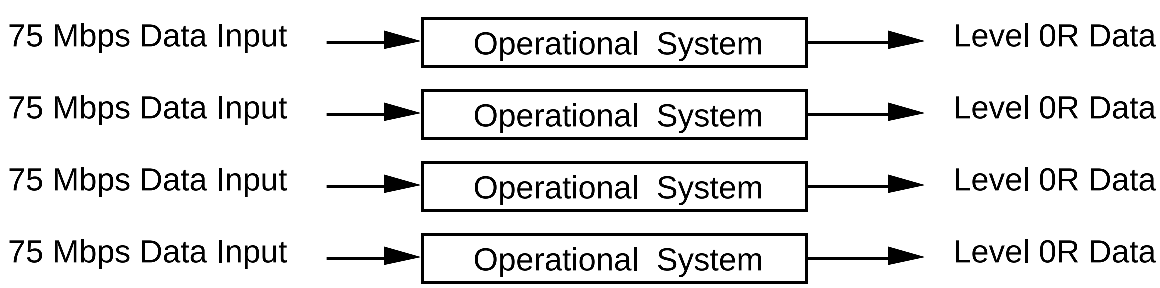


Figure C.1-3: Distributed Processing Architecture (Four LPS Strings)

C.1.4 Recommendation

This distributed architecture (Figure C.1-3) was chosen as the basis for LPS system design because it helps minimize LPS implementation costs (development, test, integration and delivery) and the impacts due to failures.

Appendix C.2 Wideband Data Capture Trade-off

C.2.1 Objective

The objective of this study is to review the capabilities and limitations of tape and disk storage options for capturing the raw wideband data received at the LPS.

C.2.2 OPTION A - Raw Data Capture to Tape

The LPS D-1 tape option uses a Sony digital data recorder configured with the EDAC D-1 Interface Adapter (IFA) hardware for capturing the raw wideband data. The EDAC D-1 IFA consists of a single board controller (SBC), a memory buffer, a Serial to Parallel Converter (SP), and the Peripheral Interface Adapter (PIA). The EDAC IFA is designed to function as a "data pipeline" between a high-speed computer interface and a high-speed recorder. See Figure 1. EDAC IFA configuration for the Sony tape recorder. The EDAC IFA provides a NRZL type data and clock interface to receive data from the LGS. Other supported interfaces are: HIPPI, SCSI-2, FDDI, and FIBER.

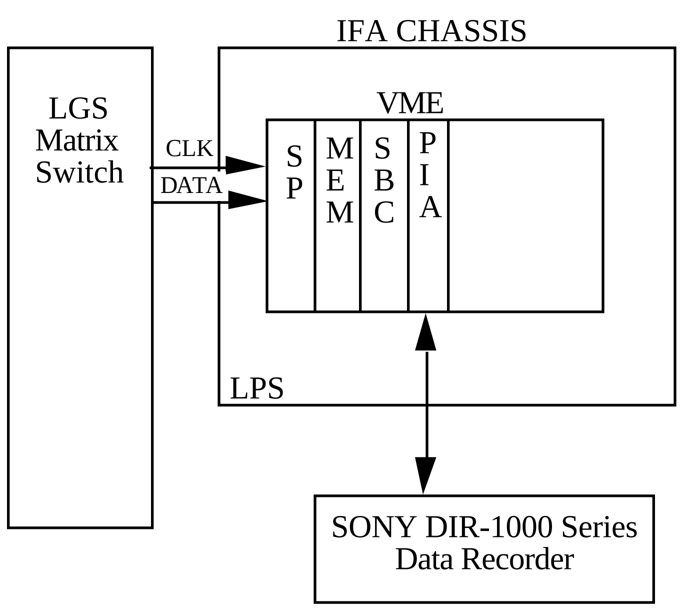


Figure 1. EDAC D-1 IFA Configuration for Sony Tape Recorder

Sony Model DIR-1000, DIR-1000M, DIR-1000L cassette based digital data recorders conform to the ANSI X3B.6 ID-1 format. The DIR-1000 series features field proven rotary head recording, providing up to 770Gbits of data storage capacity and offering seven discrete data transfer rates ranging from 8Mpbs to 256Mbps permitting high-speed data capture and replaying at a slower speeds suitable for level 0R processing. The sizes of the 19mm type D-1 cassette that can be accepted are Small, Medium, and Large representing roughly 30, 60, and 90 GB tape capacities respectively.

The LPS receives 4 ETM+ wideband data inputs at 75Mbps from the Landsat 7 satellite via the LGS directly to the EDAC IFA which would capture the it onto a DIR-1000 series recorder and playback later at a slower speed (presently determined to be 7.5 Mbps) for level 0R processing.

C.2.3 OPTION B - Raw Data Capture to Disk

The capture to disk option uses the same concept as the EDAC IFA except the data is captured to a disk and then off-loaded to a Digital Linear Tape (DLT). The primary hardware components involved are a Serial to Parallel Converter (SP), a Mizar 7772 Digital Signal Processor (DSP) board used as a Single Board Computer (SBC), a VME interface board (IFB) and a Spectra 6000 24GB Disk Array. A secondary component is a Digital Linear Tape that is used to save the raw data off line.

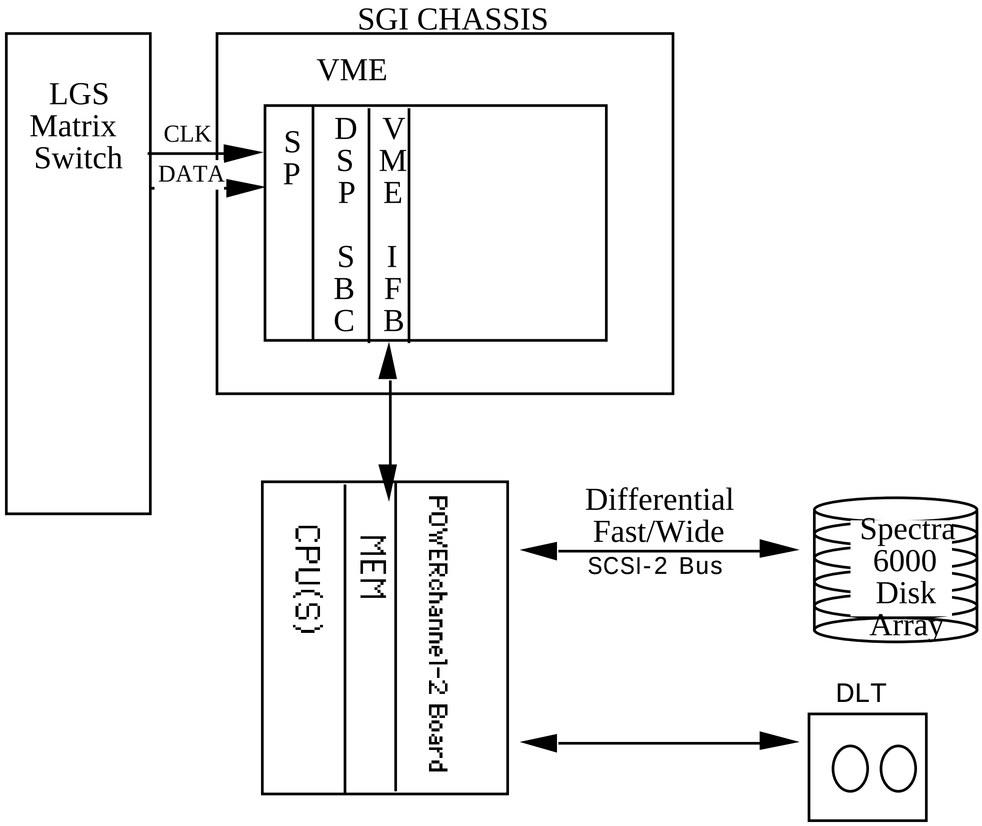


Figure 2. LPS Raw Capture to Disk Configuration

The Spectra 6000 Disk Array is manufactured by Ciprico and utilizes a RAID configuration that provides disk drive redundancy. That is, when a drive fails, the array's controller automatically shuts down the failed drive and activates the array's error-correcting feature. Special controller hardware regenerates the failed drives' data 'on-the-fly' with absolutely no performance degradation. The 'hot replacement' capability permits quick replacement of the failed drive while the array remains on line. Optional redundant power supplies further increase the array's fault tolerance. The software necessary to integrate a Ciprico array with Silicon Graphics workstations include drivers and utilities to maximize performance is also available. A graphical utility software allows users to configure or monitor the array status from any Silicon Graphics host system. The Spectra 6000 Disk Array uses SCSI-2 Fast/Wide Differential and can sustain transfer rates of 19Mbps.

The Digital Linear Tape (DLT) manufactured by Silicon Graphics is a high performance tape system capable of storing data (10GB native and 20GB compressed) on a data cartridge and sustaining transfer rates of 1.25MBps native and 2.5MBps compressed. It is comprised of a sled mount tape drive for internal use, a tabletop drive for external use and a 7 cartridge robotic mini-library. The DLT has a reliability rate of less then one unrecoverable error for 10^{17} bits read. A data cartridge can be reused over 3500 times before any problems should be experienced. The head life is 10,000 hours and the MTTF is 80,000 hours.

C.2.4 Evaluation of Data Capture Alternatives

Option A represents a commercial off-the-shelf option that stores data immediately to removable tapes and is based on proven technology. However, using the DIR-1000 tape drive delays LPS Level 0R processing until the third contact is complete because the tape recorder is single function, i.e. either record or playback. Additionally the DIR 1000 tape heads must be removed by a technician and exchanged for refurbished ones once after every 2000 hours (the minimum MTBF) of use for $15-17K. (At 10 Hours of use per day that is approximately once every 7 months.)

Option B permits simultaneous record and playback which eases operations timeline, random data access which simplifies level 0R processing, and permits rapid data availability for quick verification of data acquisition. However, Option B requires system integration and a nominal amount of software development compared to option A.

The tape head life of the DLT is 10,000 hours (the minimum MTBF) while the it's MTTF is not a factor because the DLT is not involved in raw data capture.

The MTBF for the RAID is 30,000 hours.

C.2.5 Recommendation

Option B consisting of the Ciprico Spectra 6000 Disk Array integrated with SGI Challenge is recommended for the LPS. This option offers better reliability, significantly lower life cycle cost, and lower maintenance for less money. Option B, including the SGI multi-processor and communication hardware, also provides the added capability of Level 0R processing and data buffering for forward the data to the LP DAAC.

Appendix C.3 LPS Compute Processor Trade-off

C.3.1 Objective

The objective of this study is to review and evaluate the capabilities of candidate high performance computers for supporting the selection of the best one for the LPS.

C.3.2 Background

The LPS receives 4 streams of ETM+ instrument raw wideband data from the Landsat 7 spacecraft via the LGS at 75Mbps per stream. The ingested raw data is captured to disk at 75Mbps for subsequent storing to tape, Level 0R processing, and browse and metadata file generation. A total of 55 minutes of data will be down linked per day in two groups of three 4 to 14 minute contacts for a maximum of 40GB data per string. The Level 0R processing must function at no less then 7.5Mbps to allow reprocessing of 10 percent of the total daily volume and to permit operations personnel adequate time to manage the LPS. The output files from Level 0R processing, metadata files, and browse image files must be forward to the LP DAAC within 8 hours after their generation at no less then 10Mbps. The LPS must retain 3 contacts worth of raw wideband data to facilitate sufficient time for Level 0R processing. This necessitates approximately 48 GB of disk space, approximately 24GB for raw capture (i.e. the front end) and approximately 24GB for Level 0R processing output files (i.e. the back-end).

The scope of the LPS Compute Processor study was limited to three vendors: Silicon Graphics, Inc. (SGI), Sun Microsystems (Sun) and Digital Equipment Corporation (DEC) due to a tight system design schedule, system familiarity, LPS prototyping experience, and availability from SEWP.

Design drivers and selection criteria included: cost, performance, disk space expandability, VME interface, bus bandwidth, and CPU expandability.

The Landsat 7 Processing System will be located and installed at the EROS data Center (EDC) in Sioux Falls, South Dakota. For this reason, it was highly desirable that the selected commercial-off-the-shelf (COTS) compute processor should be fast enough to satisfy all LPS data processing while minimizing the need of any specially developed hardware and/or software in the LPS design.

C.3.3 Option A - SGI Challenge L or XL Servers

The Challenge servers are based on either the 64-bit R4000 or R4400 processor and designed for distributed computing environments such as data access, resource sharing, communications services, and database management.

The midrange Challenge L can be scaled from 2 to 12 150Mhz or 200Mhz MIPS R4400 processors, supports from 64MB to 6GB of memory, from 2GB to 720GB of disk storage, and five VME64 bus slots. The Challenge's Powerpath-2 system bus provides a bandwidth of 1.2GBps between memory and processor subsystems. The Challenge L and XL incorporated the SGI HIO/IO subsystems that provides a bandwidth of 320MBps per I/O controller. Figure 1 shows a functional architecture of the SGI Challenge L.

A single 150Mhz R4400 processor operates at 91 SPECint92 and 95 SPECfp92, while the 100MHz R4400 turns in 58.3 SPECint92 and 61.4 SPECft92. A fully configured Challenge L offers 1,500 Dhrystone MIPS of performance.

The Challenge XL supports from 2 to 36, 150 MHz R4000 processors, 64MB to 16GB of memory, 2GB to 1TB of disk storage, and 5 to 25 VME64 bus slots. In its maximum configuration the XL can operate at over 4000 Dhrystone MIPS.

The difference between the Challenge L and XL is number of available slots and the size of the chassis.

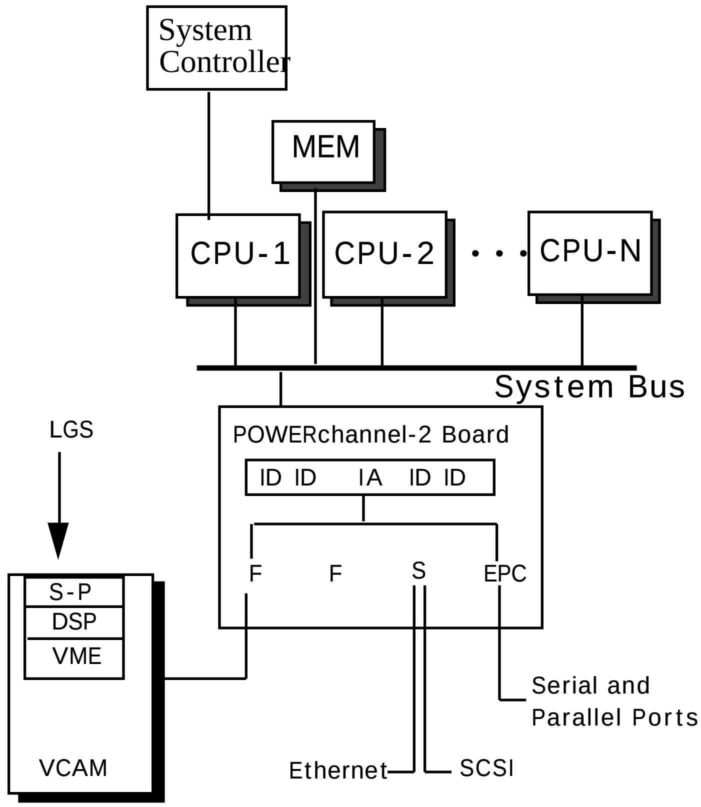


Figure 1. Functional Archetecture of SGI Challenge L

C.3.4 Option B -- Sun SPARCcenter 2000

The Sun Microsystems SPARCcenter 2000, supports up to twenty 40MHz SPARC or 50 MHz SuperSPARC+ processors, a maximum of 5GB of memory, and 500GB of disk storage.

The SPARCcenter 2000's SMP architecture supports two XD-Bus systems buses, for a total throughput of approximately 500Mbps, and up to 40 expansions slots on 10 independent Sbuses. Each bus can deliver up to 50MBps throughput with a burst throughput of 80Mbps per SBus. The main memory is configured in multiple logical units connected to only one XD-Bus while each processor and I/O bus is connected to both.

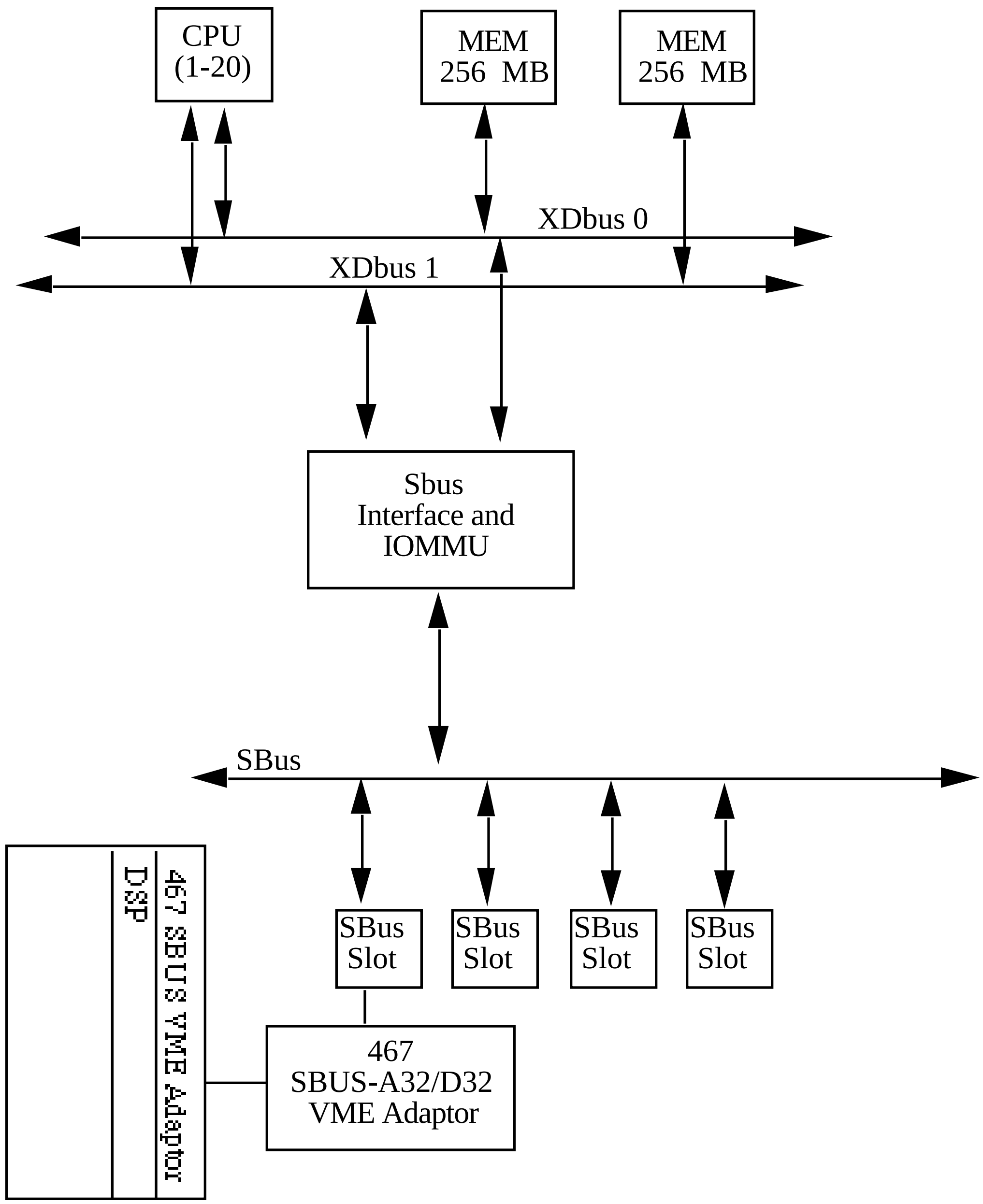


Figure 2. Functional Archetecture of the Sun SPARCcenter 2000

Sun memory, processor, and hard disk upgrades are relatively inexpensive and readily available from third-party vendors. All Sun workstation and servers come standard with a one-year warranty on parts and labor.

The VME interface is through a 467 SBus-A32/D32 VME Adaptor with DMA function that permits the interconnection of a SPARC-based workstation to any VMEbus system. It consists of two boards, one in the Sparc-based workstation and the other is in the VMEbus system slot. The two cards may be connected with a round EMI-shielded cable or optional fiber-optic cable.

C.3.5 Option C - DEC Alpha Server 2100 4/200

The AlphaServer 2100 4/200, formerly known as the Digital 2100 Server Model A500MP, is based on the DECchip 21064, a 190MHz CPU with 1 MB onboard cache, and supports up to 4 CPUs, a maximum memory of 2GB and 200GB of disk storage expandable to 500GB with disk arrays.

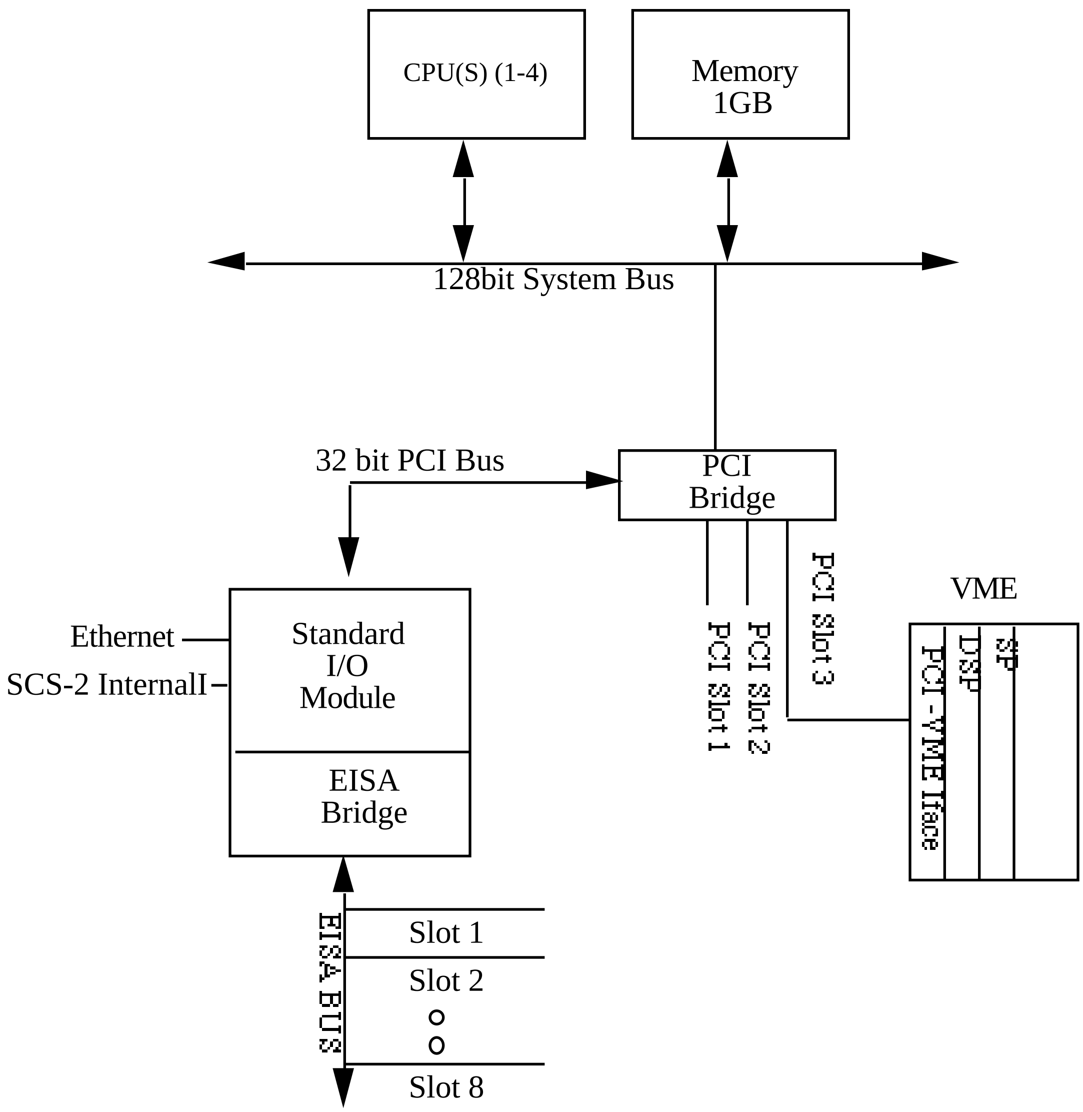


Figure 3. Functional Archetecture of DECAlphaServer 2100

The AlphaServer 2100 4/200 provides 3 PCI slots, 8 ESA slots, integral CD-ROM, integrated Ethernet and Fast-SCSI controllers, two asynchronous ports, and a parallel port. Other features include Redundant Power System, RAID, DISK Hot Swap, ECC memory, Auto Restart and Reconfiguration, Thermal Management, and an optional UPS. The SPECint and SPecfp92 ratings are 126.7 and 161 respectively, for one CPU. The operating systems supported are :DEC OSF/1 AXP, Windows NT Advanced Server, and OpenVMS AXP. Digital offers a 3 year, on-site, next day Warranty. The maximum I/O bandwidth for the PCI is 132MBps and EISA 33MBps..

At the time of this research, November 1994, technical specification or information was available on the AlphaServer 2100 4/200 PCI to VME interface card necessary for raw data capture.

C.3.6 Evaluation of Candidates

The Challenge L supports a maximum of 12 processors and offers a 1.2GBps backplane, compared to 500MBps on the SPARCcenter 2000, for near-linear scaling of performance when adding processors. Sun's sever is priced at $95,000 for a configuration with two processors, 64MB of memory, and 4.2GB of SCSI-2 disk storage. The Challenge L offers higher SPECfp92 and SPECint92 performance at a lower price.

The AlphaServer supports a maximum of 4 processors and offers a I/O bandwidth of 33Mbps for the ESA bus. The maximum memory size is 1GB if the system is configured with 4 CPUs. The LPS requires a PCI to VME interface adapter to interface with a VME rack that receives the raw wideband data from the LGS. Because the number of CPU limitations, memory limitation, lack of further information on the VME to PCI interface the AlphaServer 2100 is no a viable option.

Prototyping of CPU intensive LPS operations was performed on all three platforms. The performance of the sun SPARCcenter 2000 was significantly less then that of the AlphaServer and the Challenge L, which were about the same.

C.3.6 Recommendation

Analysis shows that the Silicon Graphics' Challenge family of computing machines meet the LPS requirements because of it's integrated VME64 interface, CPU and Memory expandability, and HIO controller with a bandwidth of 320MBps.

C.3.7 Limitations

Silicon Graphics offers a 90-day warranty, while Sun and DEC offer 1-year and three year warranties, respectively.

Appendix C.4 LPS Front-end Study

C.4.1 Objectives

This study explains the various merits and shortcomings of the six different architectures considered for the Landsat Processing System.

The requirements used to derive following architecture options for the LPS Front-End are:

- Receive and capture to tape Landsat ETM+ raw wideband data from the LGS at 75 Mbits/sec per string
- Support Frame Synchronization, CRC Check, Inverted bits, Check VC sequence Number, i.e. CCSDS Grade 3 Service.
- Perform header Reed-Solomon decoding
- Perform Bose-Chaudhuri-Hocquenghem (BCH) bit detection/correction on the frame

C.4.2 Operation Concept

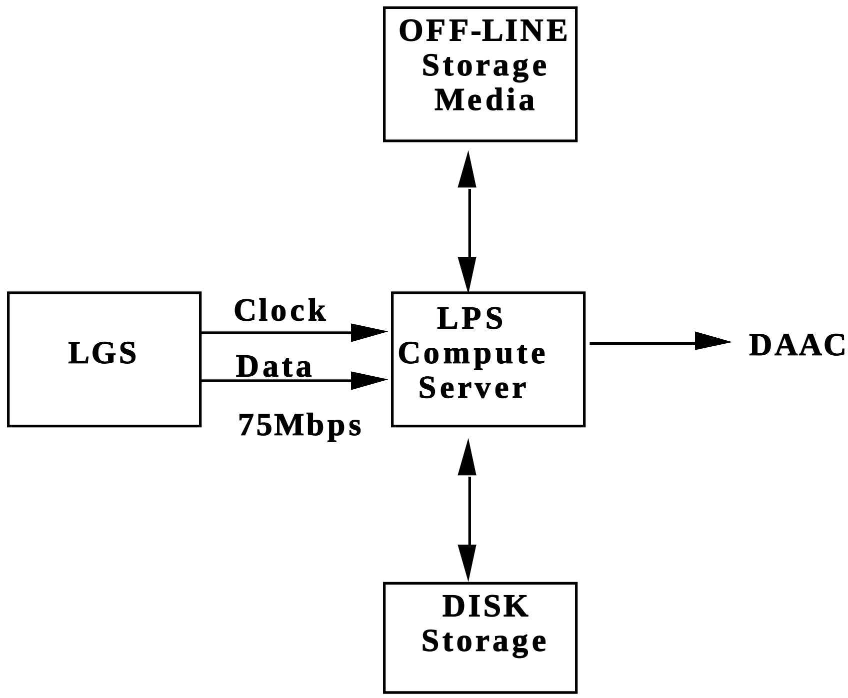


Figure C.4-1 LPS Front-End Block Diagram

LPS receives ETM+ raw wideband data during the LANDSAT 7 contact periods from the LGS during one six contacts per day. The data contact periods are received in two group of three contacts received approximately 12 hours apart. The three consequtive contacts are received in 90 minute intervals. The LPS shall record the ETM+ raw wideband data to tape, perform CCSDS and Level 0R processing to produce Level 0R, metadata, and browse Image files to transferred to a DAAC for data dissemination and accounting.

The options for the LPS front-end architecture fall into two categories: ETM+ raw wideband data capture to high speed tape, Options 1 thru 3, and raw wide band data capture to disk, Options 3 thru 6. Option 3 uses both tape and disk.

Options 1 and 2 capture the ETM+ raw wideband data onto high speed (75Mbits per second) high density (41 Gbyte) tapes during the spacecraft contact. When time permits the raw wideband data is played back at a slower rate for Level 0R processing.

Option 3 is the same as options 1 and 2 with the addition of the capability to perform frame synchronization and header Reed Solomon in real-time for subsequent data capture to fixed disk drives.

Options 4 and 5 capture the ETM+ wideband data to disk instead of the high speed high density tape. Upon completion of the contact with the spacecraft the data is simultaneously archived to off-line media and processed to Level 0R format.

Option 6, like options 4 and 5, captures raw ETM+ raw wideband data directly to disk for subsequent recording to tape and level 0R processing but uses a Mizar Single Board Computer (SBC) coupled to a Serial to Parallel Board (SPB) in lieu of the TRIPLEX or EDAC boards.

C.4.3 Evaluation Criteria

The following criteria was used to evaluate options for the raw wideband data capture and CCSDS processing.

- H/W Cost - The cost of the hardware equipment.
- NRE Cost- Non recoverable Engineering cost
- Maintenance - an estimate of the maintenance expenses expected once the systems are operational.
- Software - An estimate of the amount of software development required in Lines of Code (LOC) to implement the Data Capture (necessary), F/S, CRC, PN, Header R/S and BCH requirements.
- COTS - A measure of the amount of custom built equipment versus commercial off the shelf hardware
- Availability - the number of vendors supporting the product at present time and the outlook for the near future.
- Reliability - the probability that a system will perform in a satisfactory manner for a given period of time. Defined in terms of MTBF.
- Support - A measure of the familiarity of technology supporting the development for the LPS team.
- Maturity - the history of the product i.e. has this configuration been used before.
- Performance - a measurement of the rate of CCSDS processing
- Compatibility - the compatibility in the existing EDC environment.
- Flexibility - the ability of the product to facilitate future expansion.

C.4.4 Evaluation Scheme

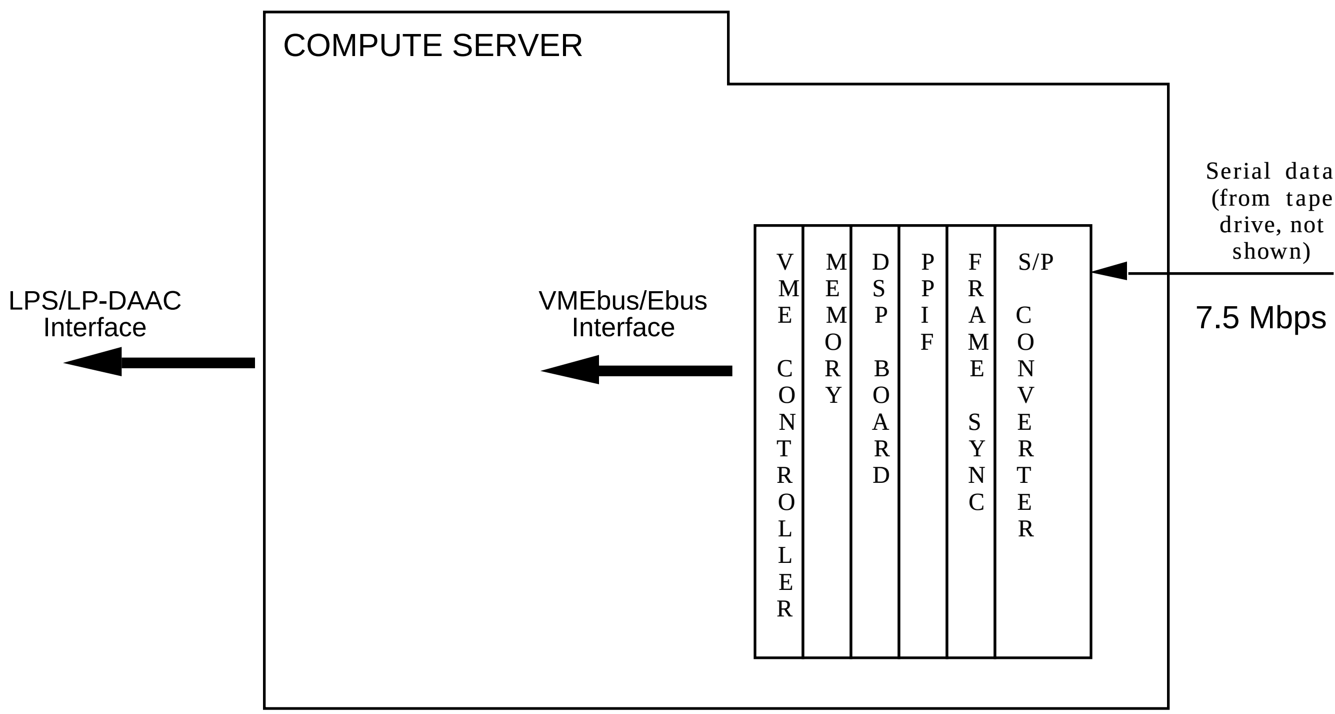
The evaluation scheme consists of a weighting and scoring scheme. Each evaluation criterion is assigned a score ranging from 1 to 5 as listed below:

Weights	Descriptions
1	Least important
2	Somewhat important
3	Important
4	Very important
5	Most important

The scoring scheme for evaluation criteria are summarized in the following tables. The candidate with the highest total scores are the prime candidate architecture.

C.4.5 Alternatives

The following paragraphs describe the candidate front-end architecture configurations that were investigated.

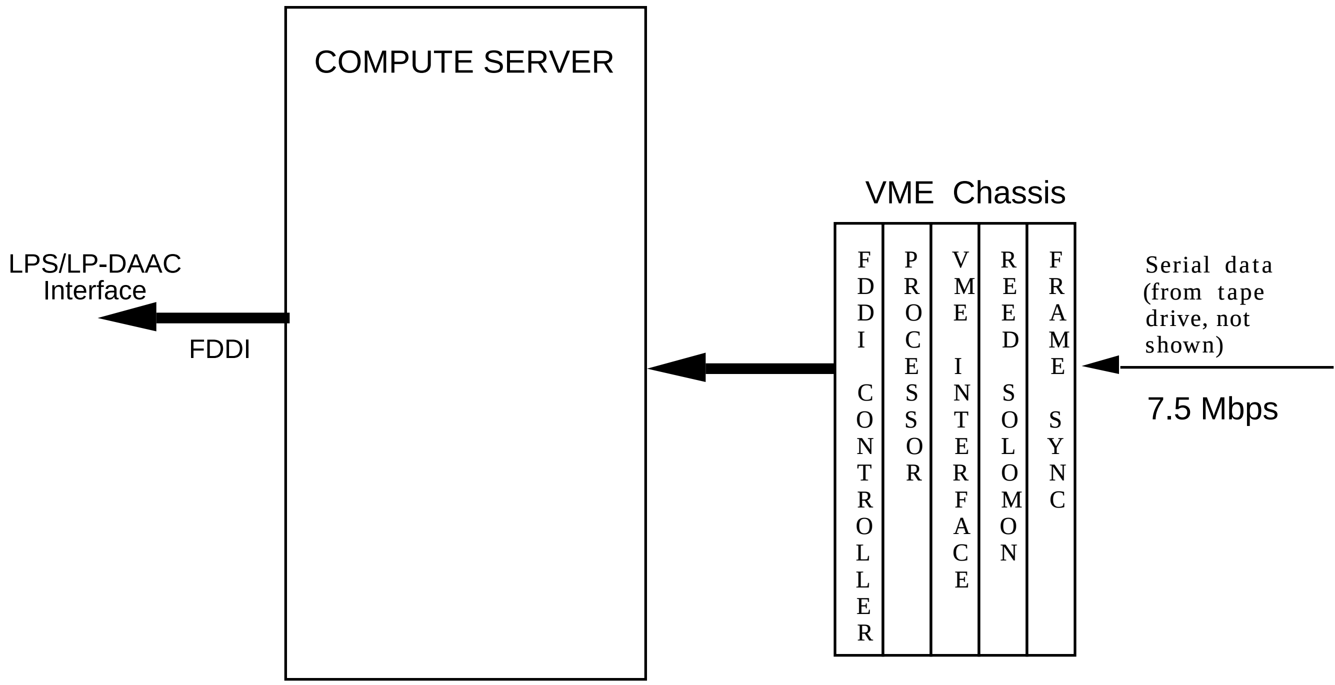


OPTION 1 - HARDWARE REUSE

This option incorporates hardware previously designed for other NASA systems.

LANDSAT 7 data is captured onto a high speed (75 Mbits/sec) high density tape (not shown) during spacecraft contact. Subsequent replay will be greater than or equal to 7.5 Mega bits per second.

The serial-to-parallel board provides 8-bit parallel data to the frame sync detector board. Data is then buffered by the Packet Processor Interface board (PPIF). The DSP board will perform header Reed Solomon and frame BCH bit checks and bit corrections. Memory is provided for additional storage prior to transfer to a compute server via a VME controller for further processing.



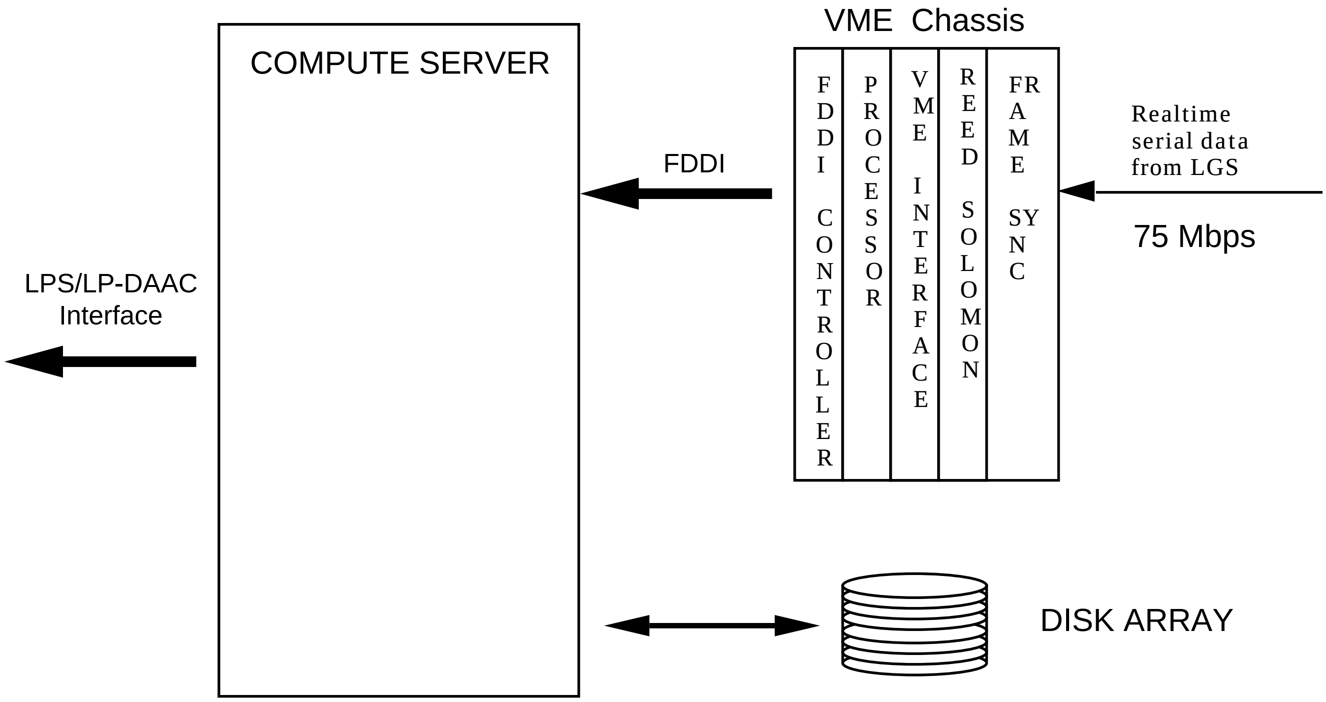
OPTION 2 - ASIC HARDWARE (< 20 Mbit/sec)

In this option, Application Specific Integrated Circuit (ASIC) technology developed by NASA is utilized in the front end hardware.

Landsat 7 ETM+ wideband data is captured onto a high speed (75 Mbits/sec) high density tape (not shown) during satellite contact periods. Subsequent replay of the data will be greater than or equal to 7.5 Mbits/sec. The front end ASIC hardware is capable of 20 Mbit/sec operation.

A separate VME chassis external to the Compute Server contains the five boards as shown above. The serial data is processed by the frame synchronizer and Reed Solomon decoder prior to transfer to the compute server via a FDDI LAN. The compute server will provide the necessary additional data processing.

This configuration specifies an external VME chassis. It is feasible to incorporate the VME boards (less the FDDI controller) within the compute server.

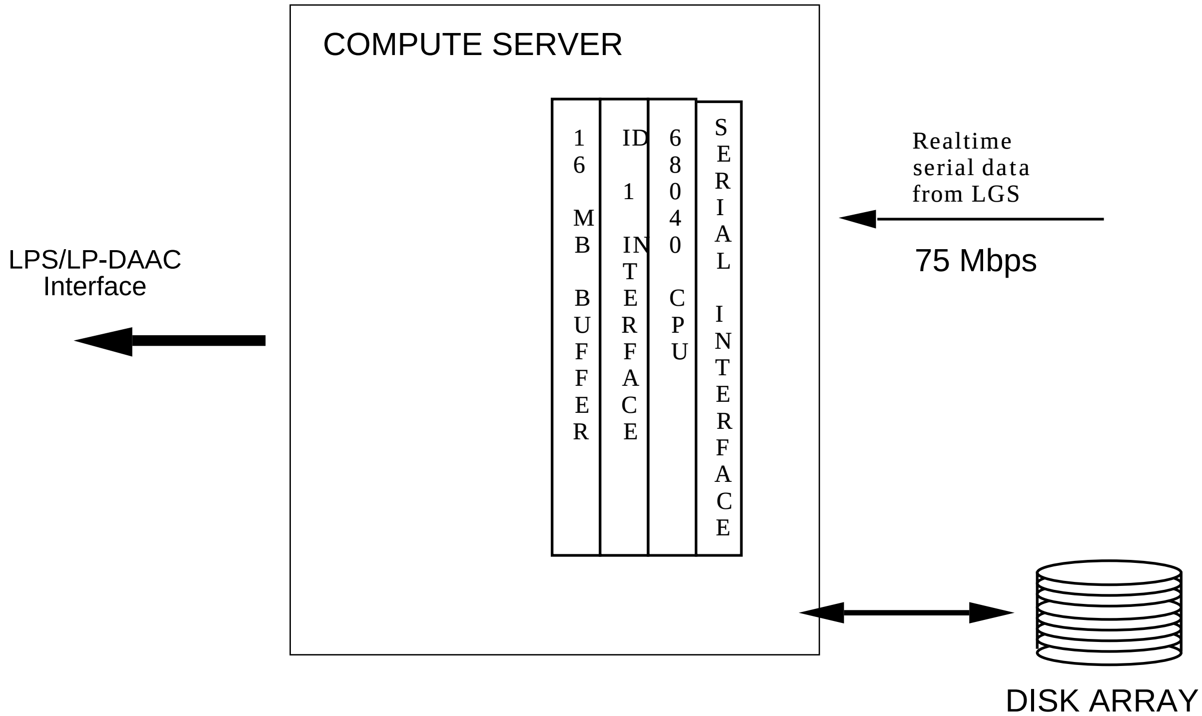


OPTION 3- ASIC HARDWARE (<150 Mbit/sec)

This option is similar to option 2 to the extent that application specific integrated circuit (ASIC) technology developed by NASA is utilized. The ASIC hardware is capable of Frame synchronization and Reed Solomon error correction at 150 Mega bits per second operation. An external high speed tape drive to capture the raw ETM+ wideband data is required.

Realtime Landsat 7 ETM+ wideband data (75 Mbits/sec) is processed by the frame sync and Reed Solomon hardware during spacecraft contact. Data is then transferred to a high speed disk array via the FDDI and a compute server for storage and subsequent post contact processing.

A separate external VME chassis contains the three boards shown above. The frame sync, Reed Solomon, and VME I/F functions from option 2 have been combined onto one circuit board. The VME boards are mounted in an external chassis may theoretically be installed in the compute server.

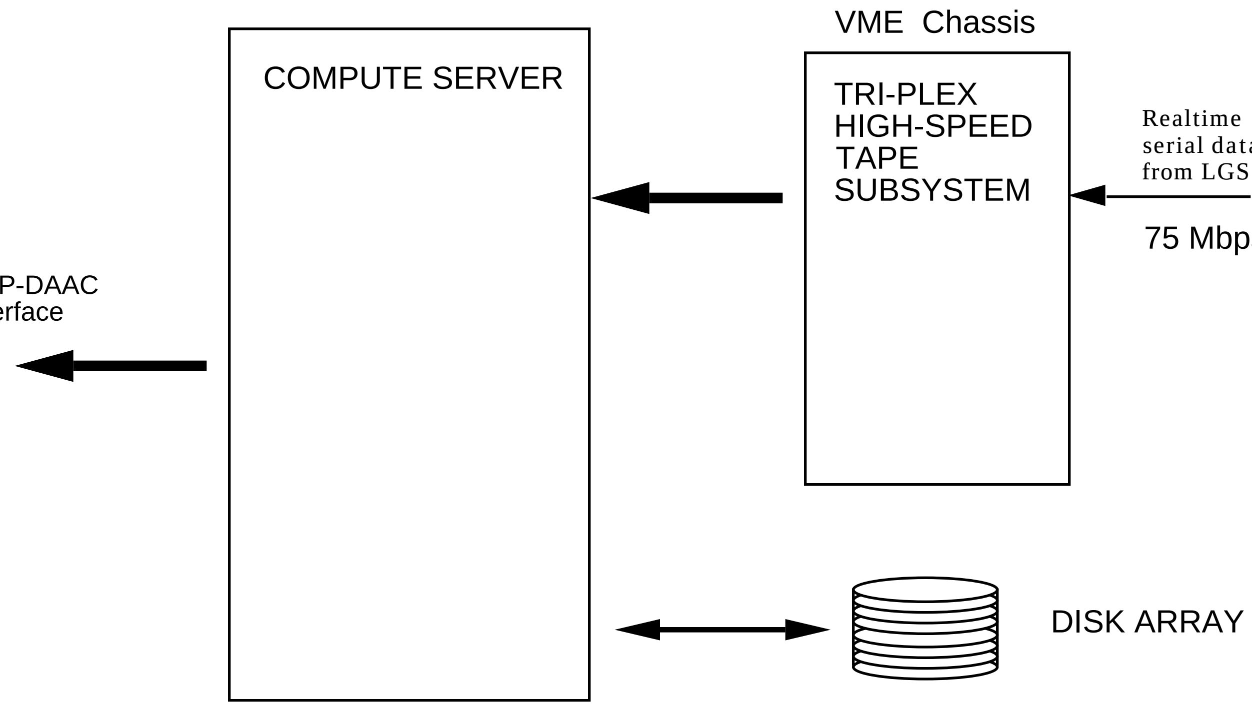


OPTION 4- MODIFIED HIGH DENSITY TAPE INTERFACE

In this architecture option, four VME circuit boards available as COTS hardware from EDAC Systems Inc. are installed in the VME chassis within the compute server. These COTS boards are designed by the manufacturer to provide an interface and control subsystem to a commercially available high-speed, high-density data acquisition tape recorder such as the Sony DIR-1000. Normally these boards are packaged in a stand-alone VME chassis which communicates to the compute server via ethernet or other communication link.

This option does not use the high-density recorder but allows the realtime data to be input directly to the serial interface board. The tape control functions of the ID-1 interface board are not used, but this board is required for the functionality of the board set. A 16 MByte buffer board is included and the 68040 board transfers the data across the VME bus via a host interface adapter.

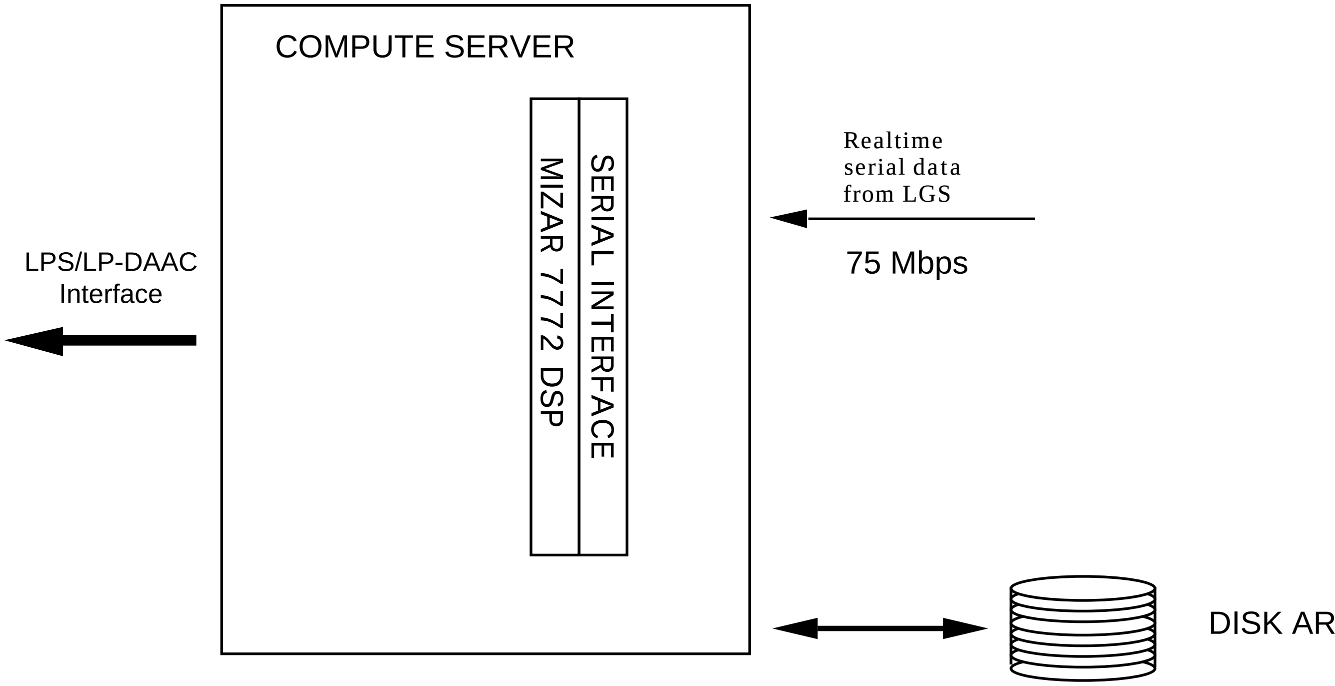
The received data is not processed by the board set but is transferred to the data capture disk array for subsequent post contact processing and storage. The costing for this option does not include any hardware modifications to the boards nor does it include the software to reside on the CPU board.



OPTION 5 - HIGH DENSITY TAPE SUBSYSTEM

This architecture option is similar to option 4 in that COTS hardware is utilized. A high-speed tape subsystem available from TRI-PLEX Systems Inc. is designed to provide an interface and control subsystem to a commercially available high-speed, high-density data acquisition tape recorder such as the Sony DIR-1000. This subsystem is provided in a stand-alone VME chassis which communicates to the compute server via a communication link.

This option does not use the high-density recorder but allows the realtime data to be input directly to the controller. The received data is not processed by the controller but is transferred to the data capture disk array for subsequent post contact processing and storage. The costing for this option does not include any hardware modifications to the subsystem or software modifications.



OPTION 6- LPS BASELINE PROTOTYPE ARCHITECTURE

This option contains two boards mounted in the compute server's VME chassis. A custom serial-to-parallel board converts the realtime data to parallel for transfer to a COTS DSP board from MIZAR Inc. The DSP board provides a communication path across the VME bus and incorporates the necessary buffering.

This option does not use the high-density recorder but allows the realtime data to be input directly to the serial interface board. The received data is not processed by either of the boards, but is transferred to the data capture disk array for subsequent post contact processing and storage.

The DSP optionally has the capability to perform data processing functions such as limited real time data quality monitoring. The serial board contains a test pattern generator to facilitate debug and test

C.4.6. Evaluation Results

There are six options for the LPS front end configuration and twelve evaluation criteria. Among them, costs, and commercial off-the-shelf availability are most important, reliability, performance, maturity, availability, and flexibility are important, support is somewhat important, and flexibility is less important.

Table C.4-1 Front-end Evaluation Scheme

Evaluation Criteria	Scoring Scheme	
H/W Cost	1	Very high cost >500K per string
	2	High cost 400-500K per string
	3	Medium cost 300-400K per string
	4	Low cost 200-300K per string
	5	Very low cost < 200K per string
NRE Cost	1	Very high cost >400K
	2	High cost 300-400K
	3	Medium cost 200-300K
	4	Low cost 100-200K
	5	Very low cost <100K
Maintenance Cost	1	Very High Maintenance Cost (>20K) per year per string
	2	High Maintenance Cost (15-20) per year per string
	3	Medium Maintenance Cost (10-15) per year per string
	4	Low Maintenance Cost (5-10K) per year per string
	5	Very Low Maintenance Cost (0-5K) per year per string
Software LOC	1	Very high LOC (>6000)
	2	High LOC (4000-6000)
	3	Medium LOC 3000-4000)
	4	Low LOC (2000 - 3000)
	5	Very low LOC <2K
Availability	5	Very Highly Commercially Available
	4	Highly Commercially Available
	3	Commercially Available
	2	Somewhat Commercially Available
	1	Not Commercially Available
Support	1	Will be supported by a few vendors
	2	Will be supported by many venders
	3	Currently supported by a single vendor
	4	Currently supported by few vendors
	5	Currently widely supported by many vendors
Reliability	1	Very low degree of reliability (MTBF<2000)
	2	Low degree of reliability
	3	Medium degree of reliability
	4	High degree of reliability
	5	Very high degree of reliability (MTBF>40,000)

Table C.4-1 Front-end Evaluation Scheme (continued)

Evaluation Criteria		Scoring Scheme
Familiarity	1	Familiarity w/ development technology scarse
	2	Familiarity w/ development technology less common
	3	Familiarity w/ development technology common
	4	Familiarity w/ development technology more common
	5	Familiarity w/ development technology high
Maturity	1	Experimental prototype
	2	Emerging, new to the field
	3	Emerging, very few users
	4	Used by some users
	5	Widely used with proven record
CCSDS w/ BCH Performance	1	Meets Requirements
Flexibility	1	Configuration is least expandable and conducive to change
	2	Configuration is less expandable and conducive to change
	3	Configuration is somewhat expandable and conducive to change
	4	Configuration is more expandable and conducive to change
	5	Configuration is most expandable and conducive to change

H/W Cost - Option 1, 2, and 3 did not score well in this area because they require the usage of an expensive high speed tape record device coupled to the compute server. Options 4, 5, and 6 capture directly to disk and don't require a high speed tape device hence a lower cost and score.

NRE Cost - Options 1, 2 and 3 require modifications to adapt existing design hence the lower score. Options 4 and 5 require engineering changes by the manufacture to accommodate the raw capture to disk versus the high speed tape. Option 6 requires engineering in the development of the raw data capture to disk.

Maintenance Cost - Options 1, 2 and 3 scored low due the usage of an ID-1 tape drive. The heads must be refurbished after every 2000 hours of usage for approximately $15K. Options 4 and 5 scored better because the hardware components have less moving parts and Option 6 scored best because it offers even fewer circuit boards then options 4 and 5.

Software Lines of Code (LOC)- Option 1 offers less software development because the CCSDS processing is done is hardware however BCH bit decoding must be developed in software. Options 2 and 3 provide raw data capture to tape and CCSDS processing and BCH bit correction through the use of custom hardware hence a very low software LOC count and score. Options 4 and 5 provide raw wide band data capture but CCSDS processing and BCH must be performed in software hence a better score then Option 6. Option 6 requires that data capture, CCSDS processing, and BCH be performed in software hence the lowest score. Note: All six options require software to perform Level 0R processing hence it was not a trade-off issue.

Availability - Options 1, 2 and 3 offer a custom built hardware design therefore their score was low, i.e. not commercially available. Options 4 and 5 offer a completely vendor supplied and supported hardware design which yielded the best score. Option 6 uses a commercial off the shelf Single Board Computer (SBC) coupled to a custom built Serial to Parallel board, to reduce costs, hence this option scored lower then options 4 and 5.

Support - Options 1, 2 and 3 scored low because they employ custom hardware hence vendor supplied equipment requires engineering, while options 4, 5 and 6 employ vendor supplied circuit boards supplied by few vendors.

Reliability -- Options 1 and 2 scored low because of the usage of an ID-1 tape drive that has a MTBF of 3,000 hours. Options 3, 4, 5, and 6 scored the same because the data flows through a "pipe" of circuit boards to a disk drive.

Familiarity - Options 1, 2 and 3 received low scores because they employ the use of embedded firmware and custom hardware while options 4, 5, and 6 scored better because the software is developed in the traditional environment.

Maturity - Options 1, 2 and 3 are currently available and in use by some users today. Options 4, 5, and 6 are new techniques hence their lower score.

CCSDS-BCH Performance - All options were scored the same because all six options meet the Level 2 requirement of 7.5Mbps.

Flexibility - Options 1, 2 and 3 offer custom hardware solutions coupled to a work station and a high speed tape device versus options 3, 4, and, 5 which offer solutions based primarily on software running on a workstation hence the scoring.

Table C.4-2a Front-end Evaluation Results

Evaluation Criteria		Option 1 (560)			Option 2 (520)			Option 3 (520 150)		
	WT	ES	WS	Remarks	ES	WS	Remarks	ES	WS	Remarks
H/W Cost	5	2	10		2	10		1	5	
NRE Cost	5	4	20		2	10		2	10	
Maintenance Cost	5	1	5		1	5		2	10	
Software LOC	5	3	15		5	25		5	25	
Availability	4	1	4		1	4		1	4	
Maturity	3	5	15		4	12		4	12	
CCSDS-BCH Perf.	3	1	3		1	3		1	3	
Flexibility	3	2	6		1	3		1	3	
Reliability	3	1	3		1	3		3	9	
Support	2	1	2		1	2		1	2	
Familiarity	2	2	4		1	2		1	2	
			87			79			85	

Table C.4-2a Front-end Evaluation Results

Evaluation Criteria		Option 4 (EDAC)			Option 5 (TRIPLEX)			Option 6		
	WT	ES	WS	Remarks	ES	WS	Remarks	ES	WS	Remarks
H/W Cost	5	3	15		3	15		4	20	
NRE Cost	5	1	5		1	5		3	15	
Maintenance Cost	5	3	15		3	15		4	20	
Software LOC	5	2	10		2	10		1	5	
Availability	4	5	20		5	20		4	16	
Maturity	3	3	9		3	9		2	6	
CCSDS-BCH Perf.	3	1	3		1	3		1	3	
Flexibility	3	4	12		4	12		5	15	
Reliability	3	3	9		3	9		3	9	
Support	2	3	6		3	6		2	4	
Familiarity	2	4	8		4	8		4	8	
			112			112			121	

C.4.7 Recommendation and Rationale

Option 6, the Raw data capture to disk via a Mizar DSP and Serial Interface card, is the recommended solution for the following reasons:

- Lowest cost among options. The vendor hardware cost of a LPS string with four processor is less then all five other options.
- Reduces the custom built Hardware - A custom Serial to Parallel was built because the cost of a COTS card.
- System replication cost is low-- With little or no custom hardware the cost to duplicate a LPS string is strictly vendor hardware.
- Minimizes the Life cycle costs by avoiding the use the high speed tape.
- Maximized flexibility -- With the intensive processing occurring in software and not hardware the system can more easily be maintained and expanded to perform other functions.

Appendix C.5 LPS Back-end Study

C.5.1 Objectives

The back-end study is to explore technologies available to support the LPS back end storage, the network communications between LPS and the LP DAAC, and the transfer of LPS files to the LP DAAC. The objectives are to meet LPS requirements, to foster future technology infusion, and to minimize the life cycle cost in general and development cost in particular.

C.5.2 Operation Concept

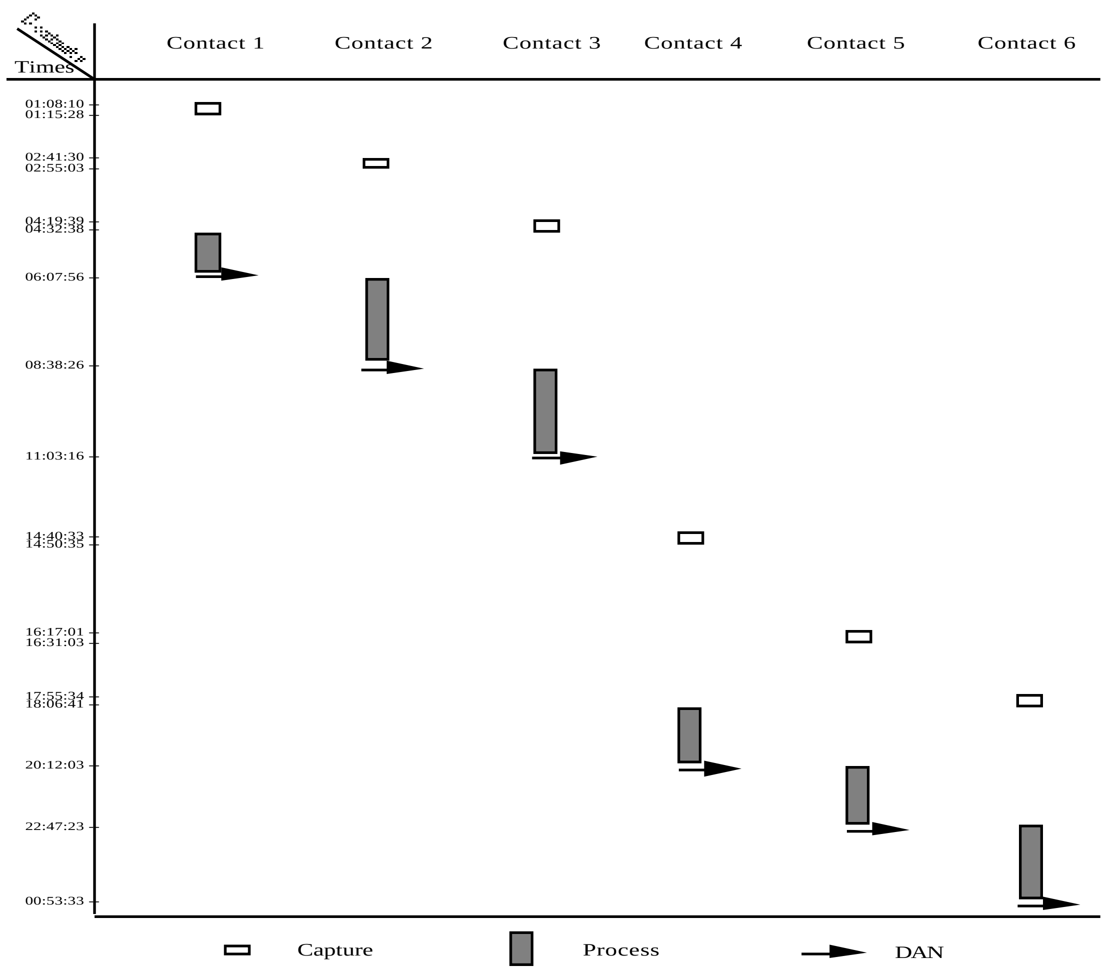


Figure C.5-1 LPS Operation Timeline

LPS captures raw wideband data during the LANDSAT 7 contact periods, processes and re-processes captured wideband data, and generates LPS files which are then made available to the LP DAAC. There are six contacts per day. Contacts are scheduled into two groups with each group has a three back-to-back contacts. The contact times and the corresponding times when the LPS captures and processes data and sends out the Data Availability Notification (DAN) to the LP DAAC are illustrated in the LPS operation timeline shown in Figure C.5-1. The operation timeline is based on the following assumptions:

- The LPS data capturing rate is 75 Mbits/sec and data processing rate is 7.5 Mbits/sec per string.
- LPS processing begins 7 minutes after the data for three back-to-back contacts are captured.
- LPS has a 15 minutes of operation time to send out a Data Availability Notification (DAN) for a given contact period.

Each LPS String uses the following protocol to coordinate the transfer of LPS files to the LP DAAC:

- Once all LPS files for a contact period are generated, LPS creates a DAN describing the available files. Each contact period may consist of several sub-intervals. Each sub-interval has several Band files, a Calibration file, a Mirror Scan Correction Data file, a PCD file, a Browse file, and a metadata file.
- LPS sends the DAN to the LP DAAC over a (BSD socket or TBD) connection. A simple authentication dialog occurs as soon as the connection is established. The connection could be established when LPS starts up and remain open at all times or opened and closed as needed.
- The LP DAAC receives and interprets the received DAN. The LP DAAC uses FTP (FTAM, or TFTP) to connect to LPS string on which the LPS files are stored and to transfer all LPS files.
- The LP DAAC uses a (BSD socket or TBD) connection to send a Data Transfer Acknowledgment (DTA) to the appropriate LPS string describing files transmission status.
- LPS receives and interprets the received DTA. It deletes unprotected files that have been successfully transferred to the LP DAAC.

- LPS receives manual over-ride directives from the operations personnel to delete or retain LPS files. LPS periodically checks the status of files and deletes files that have been on-line for at least as long as LPS's required data retention period (TBR).

C.5.3 Evaluation Criteria

The following criteria are used to evaluate options for network configuration, disk storage configuration, and file transfer.

- Cost - the development and life-cycle cost of the product.
- Availability - the number of vendors supporting the product at present time and the outlook of supports in the near future.
- Reliability - the probability of success in performing assigned functionalities by the product.
- Extendibility - the ability of the product to facilitate future expansion and foster future technology infusion.
- Maturity - the maturity and usage records of the product in the field, its compliance with common standards if currently exist, or its migration path to future standards. Since some network technologies are emerging recently and evolving rapidly, these features are very important.
- Support - the features and tools supporting the development and testing of the product. The LPS team familiarity of the product.
- Performance - the data transfer speed for network configuration and file transfer and the I/O speed for disk storage configuration.
- Compatibility - the compatibility with existing EDC or ECS network configuration. Since the LP DAAC is a part of ECS and resides in EDC.

C.5.4 Evaluation Scheme

The evaluation scheme consists of a weighting scheme and a scoring scheme. Each evaluation criterion is assigned a number weighting score ranging from 1 to 5 as listed below:

Weights	Descriptions
1	Least important
2	Somewhat important
3	Important
4	Very important
5	Most important

Each evaluation criterion is assigned a numerical score ranging from 1 to 5. The scoring scheme for evaluation criteria are summarized in the following table. The evaluation is done by assigning a score for each of the evaluation criterion for each candidate and multiplying the score by the weight to obtain the weighted score. The total candidate score is the sum of the weighted scores for all of the evaluation criteria. The candidate with the highest total scores is the prime candidate.

Evaluation Criteria	**Scoring Scheme**	
Cost	1	Very high cost
	2	High cost
	3	Medium cost
	4	Low cost
	5	Very low cost
Availability	1	Will be supported by a few vendors
	2	Will be supported by many venders
	3	Currently supported by a single vendor
	4	Currently supported by few vendors
	5	Currently widely supported by many vendors
Reliability	1	Very low degree of reliability
	2	Low degree of reliability
	3	Medium degree of reliability
	4	High degree of reliability
	5	Very high degree of reliability
Extendibility	1	Extension is not and will not be supported
	2	Extension is not but will be supported
	3	Extension will be supported but difficult to do
	4	Extension is supported but difficult to do
	5	Extension is supported and easy to do
Support	1	No tools available
	2	No expertise available
	3	Scare of tools or expertise available
	4	Tools available
	5	Tools and expertise available
Maturity	1	Experimental prototype
	2	Emerging, new to the field
	3	Emerging, very few users
	4	Used by some users
	5	Widely used with proven record

Performance	1	Performance is not satisfactory
	2	Performance is usually satisfactory
	3	Performance is satisfactory
	4	Performance is guaranteed
	5	Performance is guaranteed and much higher

C.5.5 Alternatives

The following paragraphs describe the candidate network configurations that were investigated.

- **Network Option 1.- Fiber Distributed Data Interface (FDDI).** FDDI is a fiber-optic cable standard which operates at 100 Mbits/sec and uses a dual-ring topology. The dual counter-rotating rings offer redundancy. Dual-attached workstations are attached to both rings while single-attached workstations are connected through a concentrator to both rings. Workstations attached directly to the FDDI cable have two point-to-point connections with adjacent workstations. The media access control protocol is based on token ring passing in a ring configuration. FDDI has three transmission modes: (1) asynchronous, (2) synchronous, and (3) circuit-based (FDDI-II only). Asynchronous and synchronous mode use token-passing based access method while circuit-based mode can create a dedicated communication line between two workstations with guaranteed bandwidth. FDDI standards explicitly specify certain reliability enhancing techniques such as the use of wiring concentrators and automatic optical switches to locate fault and to bypass nonfunctioning workstations. A candidate FDDI network configuration is illustrated in Figure C.5-2. The LPS strings form a backend network and is connected to the ECS backbone through an optical bypass and a router.

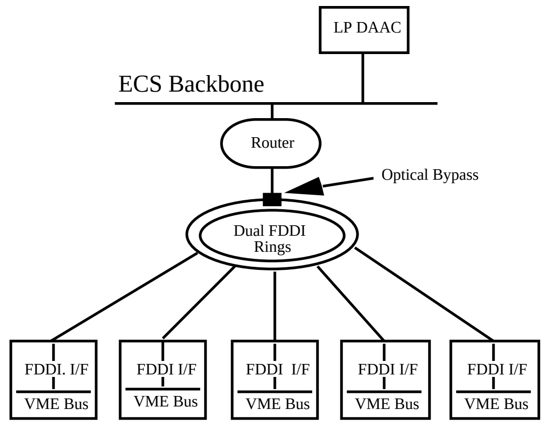


Figure C.5-2 FDDI Architecture

- **Network Option 2.- Fiber Channel.** Fiber channel is a high-speed channel that uses fiber-optic cable to interconnect computing devices in a relatively local environment. Fiber channel provides bandwidths from 133 Mbits/sec to 1 Gbits/sec over a variety of cable types, including multimode fiber, coaxial cable, and shielded twisted-pair wire. Fiber Channel offers switching services and can be used to build networks with a number of workstations. With Fiber Channel switching, many devices and networks can be connected. There are three possible connection types with Fiber Channel: (1) point-to-point connections, (2) cluster connections, and (3) switch LAN connections. The Fiber Channel interface supports variable-length transmissions. It can transmit large blocks of data without dividing it into smaller packets and thus achieve relatively high performance. A candidate Fiber Channel architecture is illustrated in Figure C.5-3 where each string is connected to a Fiber Channel switch and the switch is connected to the ECS backbone through a router.

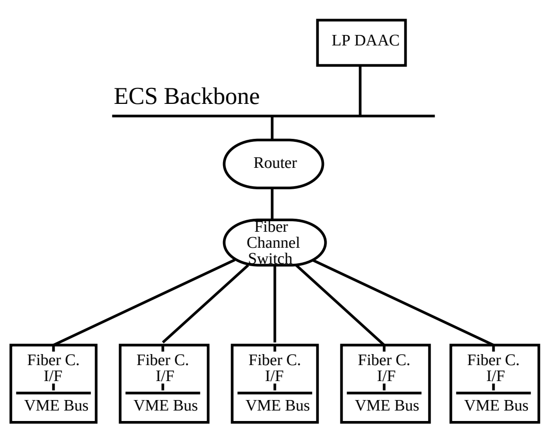


Figure C.5-3 Fiber Channel Architecture

- **Network Option 3.- Asynchronous Transfer Mode (ATM).** ATM is a high-speed data transmission technology which supports many types of traffic including voice, data, facsimile, real-time video, CD-quality audio, and imaging. ATM transfer rates are scalable, ranging from 155 Mbits/sec to 622 Mbits/sec, depending on the capacity of the physical layer. An ATM network contains ATM switches which are generally multiport devices that perform switching. Workstations are connected to an ATM network through ATM switches. ATM provides any-to-any connections and nodes can transmit simultaneously. ATM is a cell relay technology and all the cells have the same size. Since all the cells are the same size, the delay caused by conventional variable-length cells is eliminated. ATM is an emerging technology and there is no standard. Research and development have been underway in various paths. The variations and the decisions to consolidate variations will have a profound impact on the usage of ATM. A candidate ATM architecture is illustrated in Figure C.5-4 where each string is connected to an ATM switch and the ATM switch is connected to the ECS backbone through a router.

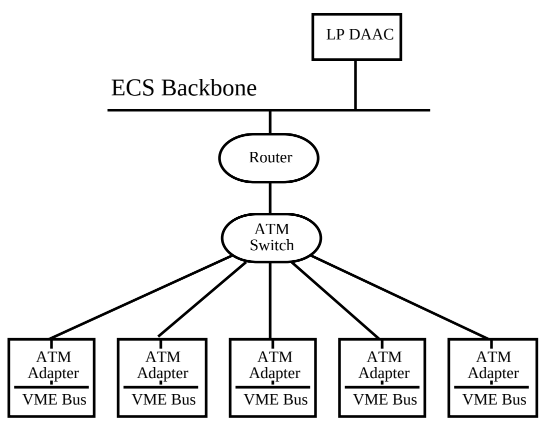


Figure C.5-4 ATM Architecture

The following paragraphs describe the candidate storage configurations that were investigated.

- **Storage Option 1.- Regular Disks.** Regular hard disk drivers or bundles as illustrated in Figure C.5-5.

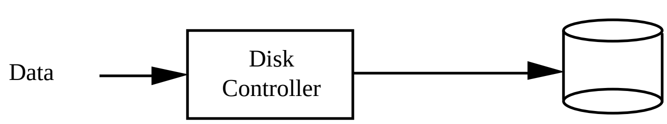


Figure C.5-5 Regular Disk

- **Storage Option 2.- Regular disks with disk mirroring/duplexing**. Disk mirroring/duplexing provides protection against disk failures. Disk mirroring and duplexing are configurations that write data to two disks simultaneously. The disks can share the same controller, or each disk can be attached to its controller. With disk mirroring, the primary drive and a backup mirroring drive share the same disk controller as illustrated in Figure C.5-6. With disk duplexing, the primary drive and the backup mirroring drive are both attached to their own controllers as illustrated in Figure C.5-7.

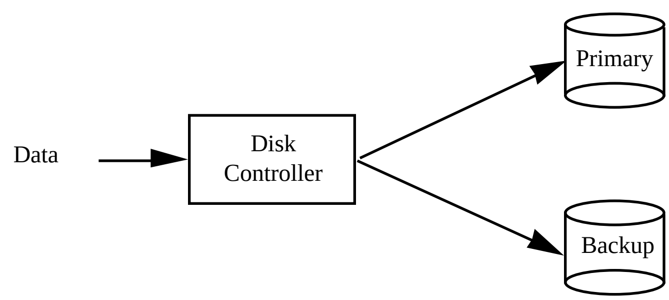


Figure C.5-6 Disk Mirroring

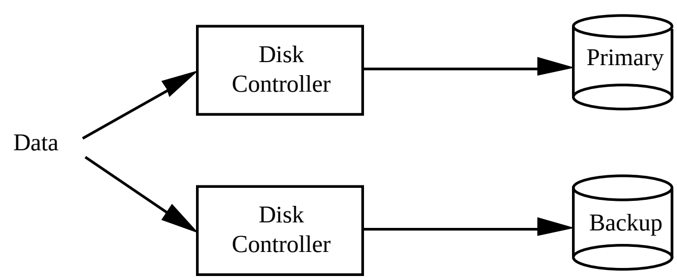


Figure C.5-7 Disk Duplexing

- **Storage Option 3.- Redundant Arrays of Inexpensive Disks (RAID).** A RAID is a set of drivers that appears as a single drive as illustrated in Figure C.5-8. Data is written evenly across the drivers by using a technique called striping. Striping improves throughput and provides a form of redundancy that protects against the failure of one disk in the array by encoding the scattered data to a backup drive known as the parity drive. In addition, RAID systems allow hot replacement of disks (i.e. disks can be replaced while the system is running). RAID provides redundancy similar to mirroring and duplexing. There are six levels of RAID. A level 3 RAID, consisting of a parity drive to provide mirroring for two or more primary drives, is currently being investigated.

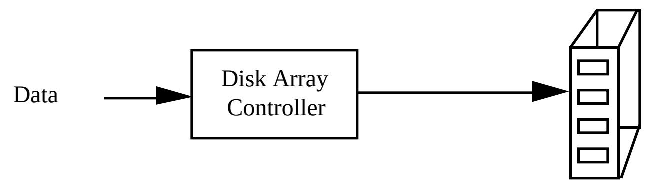


Figure C.5-8 RAID

The following paragraphs describe the candidate file transfer protocols that were investigated.

- **Protocol Option 1.- File Transfer Protocol (FTP).** FTP is a program for transferring files in a TCP/IP environment. FTP is implemented at the applications level with respect to the OSI protocol model. Its operation is based on the Telnet program and TCP. FTP uses the transport layer TCP to provide connection set-up, reliable data transfer, and data pacing. Files are transferred between systems by first establishing a session which has a data transfer and a control connections. The control connection remains open for the duration of connection, while the data transfer connection may be closed and another opened for successive file transfers. To protect against a failed server, the client sets an inactivity timer. If it expires, both connections are closed. FTP is available on a wide variety of computer systems and can be serves as a common protocol for transferring files between systems running on different platforms.

- **Protocol Option 2.- Trivial File Transfer Protocol (TFTP).** TFTP, a stripped down version of FTP, is a bare-bone file transfer facility. Unlike the FTP, TFTP does not logon to the server host using Telnet or TCP. TFTP is small and can be easily encoded on ROM to provide an initial memory image. It does not authenticate users or list directories. It only transfers files to or from a remote server.

- **Protocol Option 3.- File Transfer Access and Management (FTAM).** FTAM is an OSI standard that provides file transfer services between systems in an open environment. FTAM is implemented in all seven layers of the OSI protocol stack. It provides access to files and management of files on diverse systems. In addition, users can manipulate files down to the record level. Files are transferred between systems by first establishing a connection-oriented session. The FTAM client contacts the FTAM server and requests a session. Once the session is established, file transfer can take place. FTAM is a file system that fully compiles with the U.S. Government OSI Protocols (GOSIP). FTAM provides two optional forms of recovery: reliable service or user-correctable service. The reliable service implies that the system will keep enough context to be able to recover from major problems. This overhead may be eliminated by allowing the user to handle rare events.

C.5.6. Evaluation Results

B.5.6.1 Network Configuration

There are three options for LPS network configuration. Eight evaluation criteria are being analyzed. Among them, reliability and performance are most important, cost, maturity, and availability are important, support is somewhat important, and extendibility is least important.

		Option 1(FDDI)			Option 2(FC)			Option 3(ATM)		
Evaluation Criteria	WT	ES	WS	Remarks	ES	WS	Remarks	ES	WS	Remarks
Cost	3	5	15	• $ 6 - 7 K for a FDDI interface card	2	6	• $? K for a FC interface card • 30 - 40 K for an Optic switch	3	9	• $ 2.7K for an ATM VMEbus Adapter • 20 - 30 K for an ATM switch
Availability	3	5	15	Supported by SGI and other vendors	2	6	Supported by a third party	3	9	• Currently supported by a third party • Will be supported by SGI
Reliability	5	5	25	Dual rings offer redundancy and explicit standards offer reliability enhancing	5	25	Explicit standards offer reliability enhancing	4	20	Technical risks exist due to the lack of standards
Extendibility	3	3	9	Maximal bandwidth is fixed	4	12	Support an universal port and many connections	3	9	No standard, future migration might be a problem

Support	2	5	10	• Cost of spares and logistics support are good • Supported by SGI and many other vendors	3	6	Supported by a third party and cost of spares could be high	3	6	Supported only by Fore and hard to implement
Compatibility	4	5	20	Compatible with existing EDC networks	3	12	Not currently used by EDC	4	16	• Compatible with existing EDC networks • Provide better LAN & WAN supports
Maturity	3	5	15	Widely used for LAN and WAN with proven records	4	12	Widely used for campus-wide connections	2	6	An emerging technology with no standard and is not widely used
Performance	5	2	10	• Transfer rate < 100 Mbits/sec • Only one node can transmit at any one time • Network can be saturated	5	25	• Transfer rate < 1 Gbits/sec • Multiple nodes can transmit simultaneously	4	20	• Transfer rate is 155 Mbits/sec for Fore's VMA-200 • Multiple nodes can transmit simultaneously • Higher overhead due to the small cell size
Total		119			104			95		

B.5.6.2 Storage Configuration

There are three options for LPS output data storage. Seven evaluation criteria are being analyzed. Among them, reliability and performance are most important, cost, availability, and maturity are important, support is somewhat important, and extendibility is least important.

* For cost, figures are based on a disk size of 24 GB which is the capacity required to accommodate data for three back to back contacts.

		Option 1 (Regular Disk)			Option 2 (Mirroring)			Option 3 (RAID)		
Evaluation Criteria	WT	ES	WS	Remarks	ES	WS	Remarks	ES	WS	Remarks

Cost	3	4	12	~ 24 K *	3	9	~ 48 k *	2	6	~ 70 k *
Availability	3	5	15	Available from multiple vendors	2	6	Mirroring and duplexing software will be available in early 1995	4	12	Available from Ciprico
Reliability	5	2	10	No protection against disk failures	4	20	Provide protection against disk failures	5	25	Provide protection against disk failures
Extendibility	1	5	5	Easy expansion to 700 GB	5	5	Easy expansion to 700 GB	5	5	Easy expansion to 2 TB
Support	2	5	10	• No special tool requires. • Cost of spares and logistics support are very good	4	8	Software tools are needed from SGI	3	6	• No special tool requires • A proprietary product which ties to the manufacturer for future support and service
Maturity	3	5	15	Widely used with proven records	3	9	Used by some users with proven records	5	15	Widely used with proven records
Performance	5	4	20	SGI direct I/O for up to 80 % of hardware performance	3	15	Overhead exists due to software control	5	25	SGI direct I/O and N-way striping
Total		87			72			94		

B.5.6.3 File Transfer

There are three options for LPS file transfer. Seven evaluation criteria are being analyzed. Among them, reliability and performance are most important, availability, maturity, and compatibility are important, support is somewhat important, and extendibility is least important.

		Option 1 (FTP)			Option 2 (TFTP)			Option 3 (FTAM)		
Evaluation Criteria	WT	ES	WS	Remarks	ES	WS	Remarks	ES	WS	Remarks
Availability	3	5	15	Available from and widely supported by many vendors	4	12	Available from and widely supported by many vendors	4	12	Supported by a few vendors

Reliability	5	5	25	Very reliable through a timeout and retransmit mechanism	3	15	Not reliable due to the use of connectionless UDP	3	15	Some of the implementations so far have failed to interoperate with one another
Extendibility	1	5	5	Easy to extend or upgrade	4	4	Extension requires some efforts	4	4	Extension requires some efforts
Support	2	5	10	Known to the LPS team, information is complete, and widely available	4	8	Less information and requires some efforts	3	6	Less information and a little bit hard to implement
Compatibility	3	4	12	An Open systems protocol and compatible with many systems	4	12	An Open systems protocol and compatible with many systems	5	15	An Open systems protocol. and compatible with GOSIP
Maturity	3	5	15	Widely used with proven records	3	9	Mostly used as a bootstrap for diskless workstations	3	9	Not widely used.
Performance	5	4	20	Transfer rate is high provide no hardware limitation	5	25	Transfer rate is high provide no hardware limitation	3	15	Transfer rate is satisfactory
Total		102			85			76		

C.5.7. Recommendation and Rationale

The candidate network configurations were analyzed in the previous section based on evaluation criteria. Option 1 - FDDI was recommended because the following main reasons:

- Lowest cost among options.
- Most mature technology among options.
- Widely used with proven records and widely supported by many vendors.
- Satisfactory transfer rate. Since transfer rate is primarily bound by the load on the ECS backbone network, Fiber Channel and ATM are not cost effective options.

The candidate storage configurations were analyzed in the previous section based on evaluation criteria. Option 3 - RAID was recommended because the following main reasons:

- Best performance among options.
- Most reliable among options and support hot replacement of disks.
- Widely used with proven records.
- Disk mirroring/duplexing is not currently supported.

The candidate file transfer mechanisms were analyzed in the previous section based on evaluation criteria. Option 1 - FTP was recommended because the following main reasons:

- Better performance comparing to FTAM.
- More reliable comparing to TFTP and FTAM.
- Sufficient functionalities to support the LP DAAC file transfer.
- Widely used with proven records and widely supported by many vendors.
- Complete information and widely available expertise.

C.5.8. Standing Issues

- Under the current concept, LPS sends a DAN to the LP DAAC on a per contact period basis. To relive the burden on the LPS data output storage and to make it consistent with the LPS files generation, sending a DAN for each subinterval is worth of considering.

Appendix C.6 LPS Console Trade-offs

C.6.1 Objective

The objective of this study is to evaluate the alternatives for providing operator's console capability for the LPS.

C.6.2 Background

The LPS consists of 5 strings or pipelines for raw data capture, level 0R processing, and data dissemination to the LP DAAC. Each string consists of an interface to the LGS switch, a computing system with at least 24 bytes of disk storage, and an interface to the LP DAAC. During a typical contact with the Landsat 7 satellite 4 of the five strings will be performing raw data capture to disk. Immediately after the raw capture event, Level 0R processing must begin for each string followed by data dissemination to the LP DAAC. All of this activity must be coordinated such that one person can manage all LPS strings from a central console.

To meet this capability and not couple any two systems, an independent console configuration must be used. Additionally an X-window interface can provide remote connections to each machine from independent console.

With this configuration there are two possibilities: several X-terms or several Indy workstations with remote shells on each of the five strings. Figure C.6-1 illustrates a desired network arrangement of LPS consoles for 5 LPS strings. The primary objective is to avoid using five consoles to process four real time down link streams of data because five consoles require significantly more floor space.

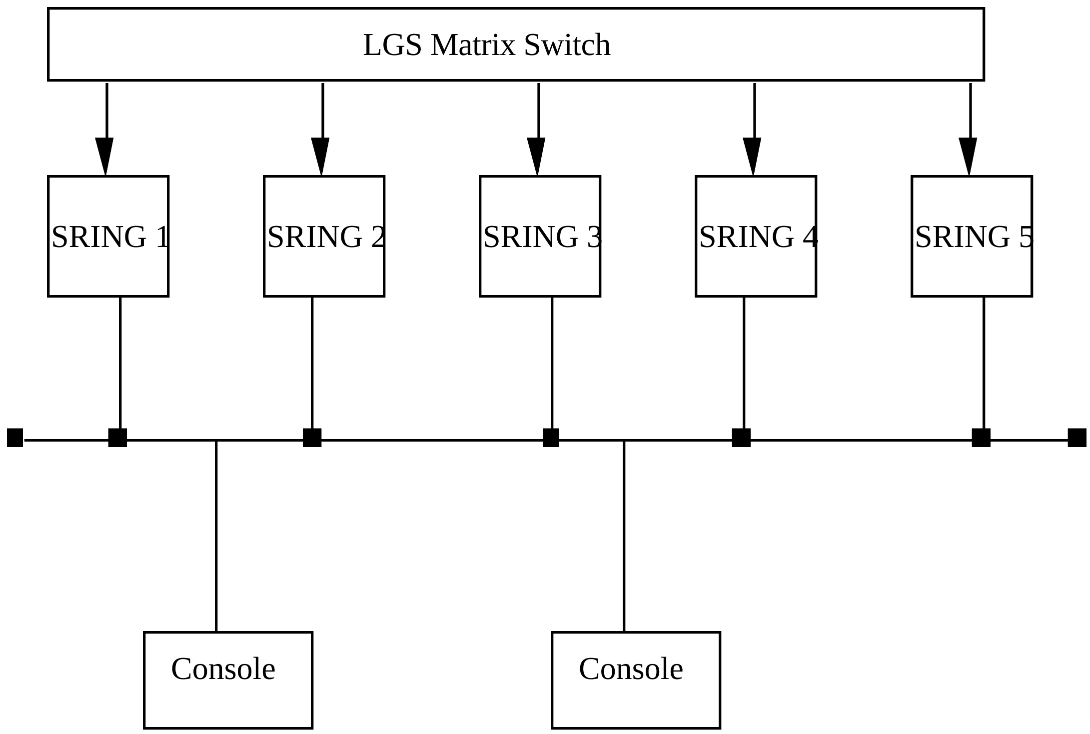


Figure C.6-1 Option A Network Arrangement for LPS

C.6.3 Option A - X-terminals

The primary components of Option A are X-terminals. They offer the cheapest viable solution. Each X-term can function independently of any and all of the strings and can boot from one or more of them. The X-Terms will permit all x-window related activity including terms, x-window graphics on any one or more of the five strings. However, any software that depends on the "GL" window code will not be usable. Additionally there is no "console" on each system.

C.6.4 Option B - Indy Work Stations

Option B consisting of two Indy Workstations are networked and perform exactly as the X term option but with added benefit of a serial interfaced to each string. This serial interface enables each Indy to perform as a console on it's respective string. Figure C.6-2 provides a sample configuration for this option. The Indy workstations provide the added value of booting independently of any of the strings and can perform non critical function such as reading "Insight", manual pages, LPS Help, and printing capability. The Indy console can also will support all the "GL" functionality on the console which includes vendor supplied disk performance tools as well as system administration tools. This can only make the management of the five LPS strings easier for the operations.

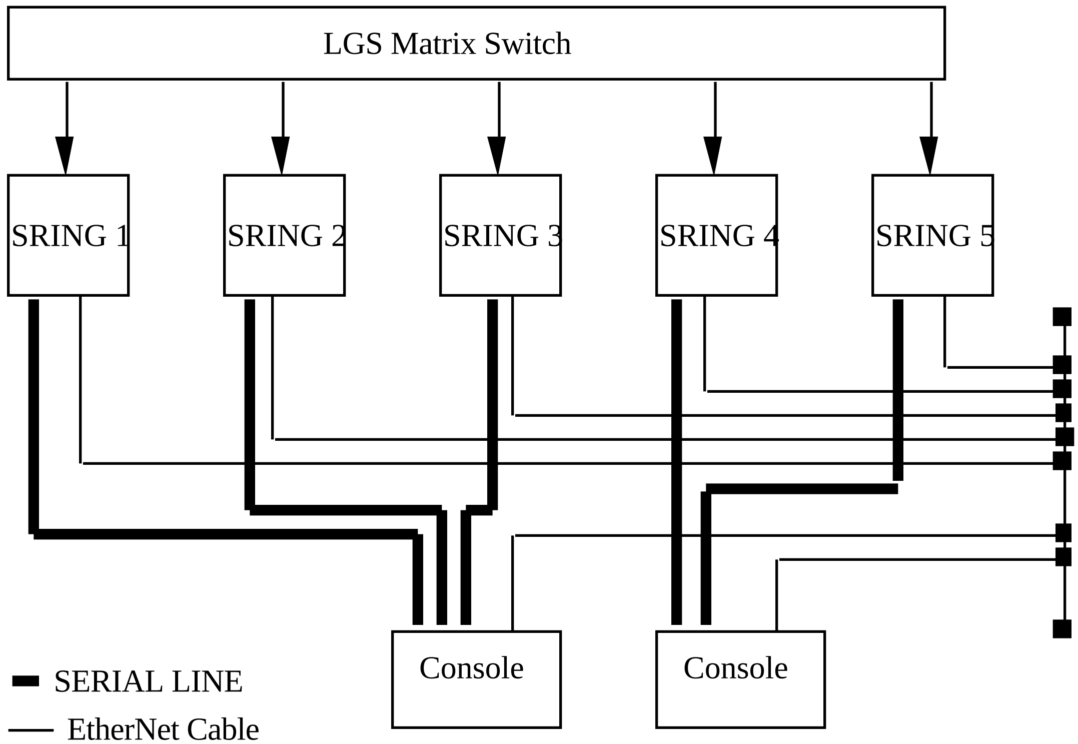


Figure C.6-2 Option B Network Arrangement for LPS

C.6.5 Evaluation

Option B costs approximately 3 times that of the x-terminal however the value added includes off-loading of non-LPS activity and full access to SGI system administration tools.

C.6.6 Recommendation

Option B is recommended because it provides the capability and options that Option A will never be able to provide including access to SGI system administration tools and off-loading of non-LPS related functions such as printing and or Help utilities.

Appendix C.7 LPS Workload/Traffic Load Estimates

C.7.1 Objective

The objective of this analysis is to conduct a review of the work (functions) to be performed by LPS under worst case conditions and determine the sizes of LPS data processing and storage resources to support the resulting traffic loads. This analysis is based on the performance requirements contained in the F&PS and the assumptions used in the LPS operations concept and system design.

C.7.2 Workload Requirements

The LPS workload related requirements are as follows:

1. The LPS shall receive and store raw wideband data from LGS is at 75 Mbps by each LPS string (F&PS 4.2.1).
2. The LPS shall receive raw wideband data contact periods of up to 14 minutes in duration (F&PS 4.3.1)
3. The LPS shall store raw wideband data for a maximum of 3 contact periods until the start of the next (fourth) contact period (4.3.2).
4. The LPS shall retrieve the stored wideband data at rates equal to or greater than 7.5 Mbps for each LPS string (F&PS 4.3.3).
5. The LPS shall receive and process an equivalent of 250 ETM+ scenes per day (F&PS 4.1.3)
6. The LPS shall receive and process the daily volume (250 ETM+ scenes) within 16 hours (F&PS 4.1.4)
7. The LPS shall provide the capability to reprocesses a maximum of 10% of daily volume (25 ETM+ scenes) per day (F&PS 4.1.5)
8. The LPS shall provide a maximum of 8 hours of on-line storage for LPS Files (F&PS 4.1.7)
9. The LPS-LP DAAC interface shall provide the capability to transfer the daily volume of LPS output files to LP DAAC at an average aggregate rate of 40 Mbps (F&PS 4.2.2).

C.7.3 Workload Assumptions

The following assumptions are used, along with workload requirements, to determine the minimum sizes of the data processing, storage and communication resources required for the LPS:

1. A total of 6 contact periods (passes) are received by LPS. The longest possible contact period for a 0 degree acquisition circle is not expected to exceed 14.01 minutes.

2. The LPS receives 6 contact periods in 2 groups of 3 contact periods. The maximum possible time for 3 consecutive contact periods in a group does not exceed 35.15 minutes for a 0 degree acquisition circle.

3. The LPS operator may start raw data record 1 minute before and 1 minute after a contact period to assure the capture of all raw data by the LPS (not used in raw data storage calculation).

4. The time interval between any two contact period groups is expected to be 8 hours or longer.

5. The raw data is recorded on the 60-day storage media at 7.5 Mbps.

6. The level 0R processed data (LPS files) is stored in on-line storage at a minimum rate of 7.5 Mbps by each string.

7. The LPS should be able to support transfer of all LPS files, generated on a daily basis, within 6 hours of the 8 hours time allocated for this purpose. The remaining 2 hours are used up by LP DAAC operations between the receipt of data availability notice (DAN) from the LPS and the start of data transfers from LPS storage.

7. The LP DAAC starts the transfer of LPS files within an hour of the receipt of a DAN from LPS.

9. The LPS output files contain a maximum of 5% overhead (applied to the raw data volume) due to the HDF format and the LPS system (not included in sizing calculation).

10. A maximum of 5% overhead is assumed for metadata file and data transfer to LP DAAC (not included in sizing calculation).

C.7.3 Raw Data Storage

The LPS receives 6 contact periods in 2 groups of 3. The LPS raw storage is sized to store raw wideband data from a maximum of 3 contact periods at a times. A minimum of 19.8 GBytes of raw data storage is required by the LPS. The following table shows sizing calculations for the raw data storage in each LPS String:

Raw Data Receive Rate per LPS String:			75	Mbps
			9.375	MBps
Contact Period Duration (3 contact periods):			35.15	Minutes
Early start and late stop time (0 minute/pass):			0	Minutes
Total Raw Data Receive time:			35.15	Minutes
			2109	Seconds
Raw Data Volume for 3 contact periods:			19772	MBytes
			19.8	GBytes
				(Minimum)
Raw Data **Average** Volume for a contact period:			**6.6**	**GBytes**
Raw Data **Maximum** Volume for the **Longest contact period (14 minutes):**			**7.875**	**GBytes**

C.7.4 60-Day Storage

The 60-day storage is recorded and saved on a contact period basis. A From raw data workload analysis, the 60-day storage media or media set should be able to store a minimum of 6.6 GBytes of data from each contact period per each string.

C.7.5 LPS File Storage

Table C.7-1 provides LPS file size estimates for the longest contact period of 14 minutes. LPS is expected to generate a total volume of 7.3 GB for the LPS files for the 14 minute contact period. For three contact periods of a maximum total duration of 35.15 minutes, the LPS requires a minimum storage of 20.2 GB for LPS files. This includes 10% overhead required to account for HDF format, LPS file headers, and data transfer overheads.

C.7.6 LPS Processor Sizing

The LPS Processor sizing analysis are provided in Tables C.7-2, C.7-3 and C.7-4.

Table C.7-1: LPS File Size Estimates for the Longest Possible Contact Period (Landsat 7 0 Degree Acquisition Circle)

Contact Period Duration:	**14**	Min.	840000	ms.
Major Frame Time			71.461	ms.
Number of Major Frames in the Contact Period:			**11755**	
Image and Fill data minor frames / Major Frame:			6410	
Cal/Restore minor frames / Major Frames:			1000	
Scan Line minor frames /Major Frame:			2	
Time code minor frames / Major Frame:			4	
	Format 1 / String A		**Format 2 / String B**	
	Bytes / minor frame			
Band 1	16		0	
Band 2	16		0	
Band 3	16		0	
Band 4	16		0	
Band 5	16		0	
Band 6	4		4	
Band 7	0		16	
Band 8	0		64	
	Bytes / Band / Contact Period			
Band 1	1,205,558,277		0	
Band 2	1,205,558,277		0	
Band 3	1,205,558,277		0	
Band 4	1,205,558,277		0	
Band 5	1,205,558,277		0	
Band 6	301,389,569		301,389,569	
Band 7	0		1,205,558,277	
Band 8	0		4,822,233,106	
Calibration	940,373,071		940,373,071	
MSCD	70,528		70,528	
Mono (deleted per SRR RID 28)	0		0	
Multiband Browse	56,510,544		0	
PCD	420,000		420,000	
Totals /String /14 min pass	**7,326,555,095**		**7,270,044,550**	
Totals for 3 passes (35.15 min)	**18,394,886,541**		**18,253,004,711**	
Totals w/ 10% O/H):	**20,234,375,195**		**20,078,305,182**	
Total:	**20,234,375,195**		**20,078,305,182**	
LPS Output Disk Storage:	**20.2**	**GB**	**20.1**	**GB**

Note: Corrected browse reduction factor from 256 to 64				

Table C.7-2 LPS SGI Challenge XL Processor Loading/Allocation Analysis

0	0	0.0	**SGI XL Processors**								0.00
Subsystem	**Process Name**	**MIPS**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Buffer Size (MB)**
0	0	0.0	RDCS/	RDPS	BCH1	BCH2	MFPS	IDPS	O/S	(Spare)	0.00
RDCS-Rcv. Raw WB Data	Serial to Parallel	N/A	RDPS				PCDS		DBMS		0.00
RDCS-Rcv. Raw WB Data	DSP Receive	N/A							MACS		0.00
RDCS-Rcv. Raw WB Data	DSP to SGI	2.3	2.3						LTDS		0.02
RDCS-Rcv. Raw WB Data	SGI to RAID	2.3	2.3								0.02
RDCS-Save Raw WB Data	RAID to SGI	0.2	0.2								0.02
RDCS-Save Raw WB Data	SGI to Tape	0.2	0.2								0.02
RDPS-Rtrv. Raw WB Data	RAID to SGI	0.2	0.2								0.02
RDPS-Sync CCSDS Frame	Find sync/Align	187.5	187.5								672.19
RDPS-Process CCSDS Grade 3	PN+CRC+Invert	187.5		187.5							0.00
RDPS-Process CCSDS Grade 3	R-S Look-up	0.1		0.1							0.00
RDPS-BCH Decode	Mission Data	184.3			184.3						0.00
RDPS-BCH Decode	Mission Data/err	156.0				156.0					0.10
RDPS-BCH Decode	Pointer Look-up	0.1		0.1							0.00
RDPS-Check VCID	Check VCID	0.0		0.0							0.00
RDPS-Gen. RL Q&A Rpt	Compute BER/QA	0.2		0.2							0.00
MFPS-Identify VCDUs &MNFMs	VCDU & MNFM IDs	0.5					0.5				0.00
PCDS-Extract PCD	Extrct & Pack	0.5					0.5				0.00
PCDS-Extract PCD	Unpcak PCD	0.4					0.4				0.00
PCDS-Extract PCD	Build PCD Cycl	0.1					0.1				0.20
PCDS-Extract PCD	Evaluate PCD	0.0					0.0				0.10
MFPS-Identify MJFMs	ETM+ MJFM Syn	2.7					2.7				0.00
MFPS-Process Bands	Dintrlv & Rverse	93.8					93.8				0.00
MFPS-Extract Cal & MSCD	Ext. Cal & MSCD	0.9					0.9				0.00
MFPS Band Alignment	Align Band	0.9					0.9				0.00
MFPS Sub-interval Detrmn.	Interval	0.0					0.0				0.00
PCDS Scene Info Calculation	Scene Info Calc	0.0					0.0				0.20
PCDS File Creation	PCD File gen	0.0					0.0				0.39
IDPS Browse File Generation	Browse File gen	29.3						29.3			0.00
IDPS Band Files Generation	Band File Gen	3.5						3.5			0.00
IDPS ACCA	AACA	46.9						46.9			0.00
MACS Metadata Generation	Metadata	0.0							0.0		0.00
LDTS DAN Generation	0	0.0							0.0		0.00
LDTS DTA Processing	0	0.0							0.0		0.00
O/S & DBMS O/H (5% 0f Total)									45.0		
	Processor Load:	**MIPS**									**Min. Main Memory**
Totals:	**Peak/Worst:**	**900.3**	**192.8**	**187.9**	**184.3**	**156.0**	**99.7**	**79.7**	**45.0**	**0.0**	**673.32**
	Nominal:	**789.1**	192.5	187.9	184.3	0.0	99.7	79.7	45.0	0.0	**MBytes**
SGI 200 Mhz Processor MIPS:	Available:	MIPS	200	200	200	200	200	200	200	200	
											Total Bus Load:
Difference: Under/(Over)	Peak/Worst:		7.2	12.1	15.7	44.0	100.3	120.3	155.0	200.0	**94.82**
	Nominal:		7.5	12.1	15.7	200.0	100.3	120.3	155.0	200.0	**MBPS**
Note: Nominal load precludes raw WB data retrieve and BCH2 error processing (correction)											

Table C.7-3 LPS Subsystem Processing Workload Analysis

	Input								Output					
Subsystem	Unit	Unit Size* (Bytes)	Factor *	Unit Rate (Units /Sec)	Data Load (MBPS)	Process Name	Instrns per Unit	MIPS	Unit	Unit Size (Bytes)	Factor *	Unit Rate (Units /Sec)	Data Load (MBPS)	Buffer Size (MB)
RDCS-Rcv. Raw WB Data	CADU Bits	0.13	1	**75000000**	9.38	Serial to Parallel	N/A	N/A	CADU Bytes	1	0.13	9375000	9.38	0.000
RDCS-Rcv. Raw WB Data	CADU Bytes	1	1	9375000	9.38	DSP Receive	N/A	N/A	CADU Bytes	4	0.25	2343750	9.38	0.000
RDCS-Rcv. Raw WB Data	CADU Bytes	4096	0.001	2289	9.38	DSP to SGI	1000	2.3	CADU Blocks	4096	1	2289	9.38	0.025
RDCS-Rcv. Raw WB Data	CADU Blocks	4096	1	2289	9.38	SGI to RAID	1000	2.3	CADU Blocks	4096	1	2289	9.38	0.025
RDCS-Save Raw WB Data	CADU Blocks	4096	**0.10**	229	0.94	RAID to SGI	1000	0.2	CADU Blocks	4096	1	229	0.94	0.025
RDCS-Save Raw WB Data	CADU Blocks	4096	1	229	0.94	SGI to Tape	1000	0.2	CADU Blocks	4096	1	229	0.94	0.025
RDPS-Rtrv. Raw WB Data	CADU Blocks	4096	1	229	0.94	RAID to SGI	1000	0.2	CADU Blocks	4096	1	229	0.94	0.025
RDPS-Sync CCSDS Frame	CADU Blocks	1	4096	937500	0.94	Find sync/Align	200	187.5	CADUs-FS	**1040**	0.001	901	0.94	**672.19**
RDPS-Process CCSDS Grade 3	CADUs-FS	1	1040	937500	0.94	PN+CRC+Invert	200	187.5	CADUs-FPC	1040	0.001	901	0.94	0.003
RDPS-Process CCSDS Grade 3	CADUs-FPC	**8**	1	901	0.01	R-S Look-up	100	0.1	CADUs-G3	**10**	1	901	0.01	0.000
RDPS-BCH Decode	CADUs-G3	0.13	**0.98**	7370192	0.92	Mission Data	25	184.3	CADUs-BCH	**6**	0.0001	901	0.005	0.000
RDPS-BCH Decode	CADUs-G3	0.13	**0.01**	62400	0.01	Mission Data/err	2500	156.0	CADUs-BCH	**8**	0.01	901	0.007	0.104
RDPS-BCH Decode	CADUs-G3	**4**	0.004	901	0.004	Pointer Look-up	100	0.1	CADUs-BCH	**4**	1	901	0.004	0.000
RDPS-Check VCID	CADUs-BCH	1	0.001	901	0.001	Check VCID	50	0.0	VCDU Annotn	**10**	1	901	0.009	0.000
RDPS-Gen. RL Q&A Rpt	RDPS Outputs	38	1	901	0.034	Compute BER/QA	210	0.2	RL Q&A Rpt	512	**0.003**	3	0.001	0.002
MFPS-Identify VCDUs &MNFMs	VCDU Annotn	**8**	**0.01**	901	0.01	VCDU & MNFM ID	500	0.5	VCDU/MN IDs	16	1	901	0.014	0.000
PCDS-Extract PCD	PCD Bytes/v	**4**	0.004	901	0.004	Extrct & Pack	500	0.5	PCD Bytes/p	**5**	0.80	721	0.004	0.000
PCDS-Extract PCD	PCD Bytes/p	5	1	721	0.004	Unpcak PCD	500	0.4	PCD Bytes/u	**1**	0.20	144	0.0001	0.000
PCDS-Extract PCD	PCD Bytes/u	1	1	144	0.0001	Build PCD Cycl	500	0.1	PCD Cycle	**65536**	0.00002	0.002	0.0001	0.20
PCDS-Extract PCD	PCD Cycle	65536	1	0.002	0.0001	Evaluate PCD	500	0.0	PCD	65536	1	0.002	0.0001	**0.10**
MFPS-Identify MJFMs	VCDU/MN IDs	16	1	901	0.014	ETM+ MJFM Syn	3000	2.7	L0R Q&A	512	**0.001**	1.18	0.0006	0.002
MFPS-Process Bands	CADUs-BCH	1	1	937500	0.94	Dintrlv & Rverse	100	93.8	MNF/MJFM	85	0.01	11029	0.94	0.0003
MFPS-Extract Cal & MSCD	MNF/MJFM	95	1	9868	0.94	Ext. Cal & MSCD	95	0.9	Files	95	1	9868	0.94	0.0006
MFPS Band Alignment	MNF/MJFM	85	1	11029	0.94	Align Band	85	0.9	Algned Bands	85	1	11029	0.94	0.0005
MFPS Sub-interval Detrmn.	L0R Q&A	512	1	1.18	0.004	Interval	1000	0.001	Interval	12	43	50	0.00	0.0016
PCDS Scene Info Calculation	PCD	65536	1	0.002	0.0001	Scene Info Calc	10000	0.0000	Scene Info	100	655	1.4423	0.0001	0.20
PCDS File Creation	PCD	65536	1	0.002	0.0001	PCD File gen	1000	0.0000	File	65536	1	0.0022	0.0001	0.39
IDPS Browse File Generation	Algned Bands	16	0.19	58594	0.94	Browse File gen	500	29.30	File	1	0.06	3662	0.004	0.0001
IDPS Band Files Generation	Algned Bands	85	1	11029	0.94	Band File Gen	320	3.53	File	85	1	11029	0.94	0.004
IDPS ACCA	Algned Bands	1	0.50	468750	0.47	AACA	100	46.88	ACCA	1	1	468750	0.47	0.0000
MACS Metadata Generation	Q&A Data	1125	1	2.81	0.003	Metadata	1000	0.003	Metadata	4	0.004	0.010	0.0000	0.003
LDTS DAN Generation				0.004			1000	0.0000						
LDTS DTA Processing				0.004			1000	0.0000						
Total:					**48.4**			**900.3**					**46.5**	**673.3**

Table C.7-4 LPS Processor Sizing Assumptions

LPS System Sizing Assumptions		
Input Data Rate:	75000000	bits/sec
	75	Mbps
	9375000	Bytes
	9.375	MBytes
Input CADU Rate:	9014.42	CADUs/sec
Max. Duration of a Contact Period:	14	minutes
	840	seconds
No. of Contact Periods/Day:	6	
CADU Size:	1040	Bytes
CADU Sync Bytes:	4	Bytes
VCDU Size:	1036	Bytes
VCDU CRC:	2	Bytes
VCDU Header Size:	8	Bytes
Mission Data Zone:	1026	Bytes
- Mission Data:	982	Bytes
- Status/PCD Field:	10	Bytes
- Mission Data BCH Code:	30	Bytes
- Data Pointer Field:	2	Bytes
- Pointer BCH:	2	Bytes
ETM+ minor frame:	85	Bytes
No. of minor frames / VCDU:	11.55	
LPS Processing Rate:	7500000	bits/sec
	7.5	Mbps
	937500	Bytes/sec
	0.9375	MByes/sec
Process to input rate Factor:	0.1	
CADUs /sec:	901	
Landsat 7 BER	0.000001	
PCD Bytes/VCDU	4	
Packed PCD Bytes	5	
Unpackd PCD Bytes	1	
PCD Bytes/PCD minor frame	128	
PCD minor frames/Major Frame	128	
Major Frames/PCD Cycle	4	
ETM+ Scene Time	23.9	seconds
Q&A results	2	Bytes
Smallest Contact Period	23.9	seconds

C.7.8 LPS Data Transfer

Table C.7-1 shows that LPS will generate a minimum of 20.2 GB of LPS output file data for 3 contact periods for transfer to the LP DAAC. The LPS daily volume, collected over 6 contact periods, is therefore 40.4 GB. The LPS is expected to transfer the daily volume within a day's period (24 hours). This results in a minimum average aggregate (over 24 hours) data rate of 3.75 Mbps per each string. Allowing 1 hour per contact period for the DAN/DTA handshake, 18 hours would be actually available to transfer the daily volume to the LP DAAC. This results in a desired average aggregate data rate of 5 Mbps per each string. Allowing a 100% communication overhead, each LPS string is required to support an average aggregate data transfer rate of 10 Mbps to the LP DAAC.

Appendix C.8 LPS Performance Analysis

C.8.1 Objective

The objective of this performance analysis is to assess the response and/or latency of the LPS under typical workloads conditions (0 degree acquisition circle/contact periods) and for the selected hardware configuration.

C.8.2 LPS Latency Analysis

Tables C.8-1 through C.8-4 and Figure C.8-1 provide an overview of the LPS performance analysis.

C.8.3 LPS Hardware Performance Analysis

These analysis are provided in Section 2.7.2 of the SDS.

Table C.8-1: Analysis on the LPS Processing Latency

(for 0 Degree Acquisition circle/Longest Possible Contact Period and LPS Output Granule Size - Sub-interval

	(* Note 2)				(* Note 1)	**Total Duration - minutes**		
Contact Number	**Contact Start**	**Contact End**		**Duration**	***Replay Time**	**Ref: 0 Degree Table (Cycle 1)**		
1	01:07:30	01:15:28		00:07:58	01:19:36		**7.96**	0:07:58
2	02:41:28	02:55:03		00:13:35	02:15:54		**13.59**	0:13:35
3	04:20:03	04:32:38		00:12:35	02:05:54		**12.59**	0:12:35
				00:34:08	05:41:24			
						ΔTime between 3 and 4 =		10:07:55
4	14:40:33	14:51:05		00:10:32	01:45:24		**10.54**	0:10:32
5	16:17:00	16:30:59		00:13:59	02:19:48		**13.98**	0:13:59
6	17:55:34	18:06:18		00:10:44	01:47:18		**10.73**	0:10:44
				00:35:15	05:52:30			
						ΔTime between 6 and 7 =		07:41:56
7	01:48:14	01:59:40		00:11:26	01:54:20			
Start Data recording =		01:07:30						
Stop Data recording =		04:32:38						
		03:25:08	=	Wall time to record data for contacts 1-3				
Start Data recording =		14:40:33						
Stop Data recording =		18:06:18						
		03:25:45	=	Wall time to record data for contacts 4-6				
	***Note 1: Replay Time =**		10	times less than the received rate =		7.5	Mbps	
	*** Note 2: Contact Start is adjusted backward for 0 degree start, End time is not changed.**							

Table C.8-2: LPS Raw Data Processing and Contingency Times

Latency for contact #1			**Latency for contact #4**		
Delivery clk starts	01:15:28		Delivery clk starts	14:51:05	
Record data	03:25:08		Record data	03:25:45	
Replay Time	01:19:36		Replay Time	01:45:24	
Operations	00:15:00		Operations	00:15:00	
Data available	06:15:12		Data available	20:17:14	
Time to process	**01:34:36**		**Time to process**	**02:00:24**	
Latency for contact #2			**Latency for contact #5**		
Start processing	06:15:12		Start processing	20:17:14	
Record data	00:00:00		Record data	00:00:00	
Replay Time	02:15:54		Replay Time	02:19:48	
Operations	00:15:00		Operations	00:15:00	
Data available	08:46:06		Data available	22:52:02	
Time to process	**02:30:54**		**Time to process**	**02:34:48**	
Latency for contact #3			**Latency for contact #6**		
Start processing	08:46:06		Start processing	22:52:02	
Record data	00:00:00		Record data	00:00:00	
Replay Time	02:05:54		Replay Time	01:47:18	
Operations	00:15:00		Operations	00:15:00	
Data available	11:06:59		Data available	00:54:20	
Time to process	**02:20:54**		**Time to process**	**02:02:18**	
Contacts 1-3(process)=		**06:26:24**	**Contingency time (contacts 1-3) =**		**03:41:31**
Contacts 4-6(process)=		**06:37:30**	**Contingency time (contacts 4-6) =**		**01:04:26**

Table C.8-3: Time Between the Receipt of Data at LPS and Sending of Data Availability Notice (DAN)

Contact Number	Contact Stop	DAN sent		Delay				
1	01:15:28	06:15:12		04:59:44				
2	02:55:03	08:46:06		05:51:03				
3	04:32:38	11:06:59		06:34:21				
4	14:51:05	20:17:14		05:26:09				
5	16:30:59	22:52:02		06:21:03				
6	18:06:18	00:54:20		06:48:02				
7	01:59:40							
Must transfer data from contacts 1-3 to LP DAAC by this time:					14:51:05			
Therefore LP DAAC must transfer contacts 1-3 within: (time from DAN sent to DTA received by LPS)					**08:35:53**	Hours		

Table C.8-4: Analysis for LPS Data Storage and Transfer

Contact	Duration		Seconds	Data Size (GB)		Data Available	Begin Transfer	End Transfer		
1	00:07:58		478	19.70		06:15:12	10:45:11	11:50:52		
2	00:13:35		815	33.64		08:46:06	13:16:05	15:08:12		
3	00:12:35		755	31.16		11:06:59	15:36:59	17:20:51		
	00:34:08		2,048	84.50		**(4 Strings/3 Contacts)**		**Per String Avg. (GB):**		**21.12**
4	00:10:32		632	26.09		20:17:14	00:47:14	02:14:12		
5	00:13:59		839	34.60		22:52:02	03:22:02	05:17:22		
6	00:10:44		644	26.56		00:54:20	05:24:20	06:52:51		
	00:35:15		2,115	87.24		**(4 Strings/3 Contacts)**		**Per String Avg. (GB):**		**21.81**
	TOTALS =		**4,163**	**171.74**		**(4 Strings/6 Contacts)**				
EDC Delay (max.) =			270	minutes	(Selected Parameter)					
Transfer Rate (min.) =			40	Mbps	(Selected Parameter)					
Note 3: includes 10% output data overhead										

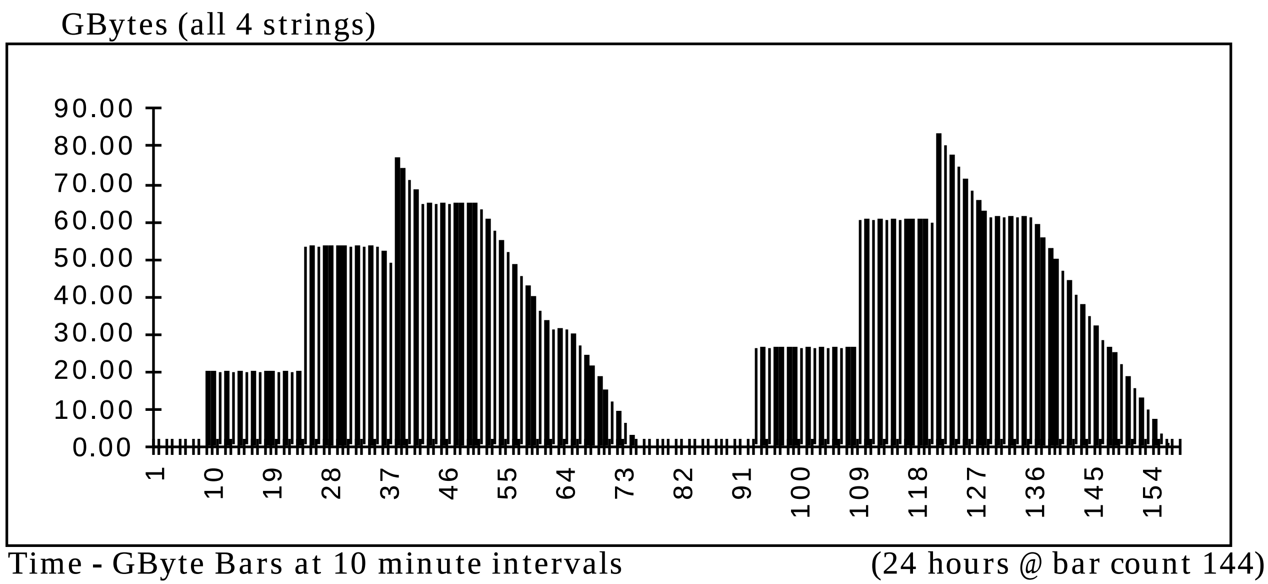


Figure C.8-1: Analysis for LPS Data Storage and Transfer (Graphic Details for Table C.8-4)

Appendix C.9 LPS RMA Analysis

C.9.1 Objective

The objective of this analysis is to assure that the LPS hardware configuration, consisting of 5 independent strings, adequately meets and/or exceeds the LPS operational availability (Ao) requirements of 0.96 as defined and specified in the LPS F&PS.

C.9.2 Assumptions

The LPS RMA analysis is based on the following assumptions:

1. The LPS consists of 5 logically independent and identical strings.

2. A maximum of four strings are required at all times to support LPS operations.

3. The hardware configuration for each LPS processing string is as shown in Figure 2.6 of the SDS.

4. The following effort (maximum times) is required to switch out the malfunctioning string and switch in the fifth string to restore LPS operations:

- Time to detect LPS processing string problem: 5 minutes
- (a) Time to repossess fifth string from LPS development/test: 10 minutes

  (It may take longer than 10 minutes if the fifth string

  requires reconfiguration to support LPS operations.) (OR)

  (b) Time to repair failed string if spares available at site: 120 minutes

  (c) Time to repair failed string if spares not available at site: 8 hours

  (includes expected response time for vendor maintenance)
- Time to bring-up LPS programs on fifth string: 15 minutes
- Time to test LPS operations on fifth string: 10 minutes
- Time to test the fifth string with LGS and LP DAAC: 15 minutes

C.9.3 LPS RMA Analysis

LPS RMA analysis were performed in two steps. single string RMA calculations, and all (5) strings (LPS) RMA calculations. These calculations are shown in Table C.9-1a and C.9-b and C.9-2, respectively.

The first step is used to calculate the MTBF and availability of a single LPS string. The first step calculations are used the overall availability of a single string using the Mean Time Between Failure (MTBF) data available on all the hardware in a string which must be always be operational to make the whole string operational. Redundant hardware items, if any, are also considered in this analysis.

The second step is performed for two configurations of the LPS, a 4 string LPS and a 5 string LPS. Both configurations of the LPS use 4 strings for LPS operations. The fifth string, if any, is used as a back-up to the 4 operational strings. RMA analysis and results for the 4 string and 5 string LPS configurations are shown in Tables C.9-1a and C.9-b, respectively.

Detailed information on performing RMA analysis, definitions and calculations are provided in Applicable Document 8 (SSDM Guidelines).

C.9.4 Results of RMA Analysis

The following results are derived from RMA analysis of the LPS hardware and architecture (string configurations):

1. A 4 string LPS can meet the LPS RMA requirements (operational availability (Ao) of 0.96 and MTTRes of 4 hours) provided that EDC has adequate spares and maintenance personnel available at site to repair the failed string within 3 hours. This would allow EDC maintenance personnel sufficient time to complete all system checkout activities and restore LPS operations during the fourth hour.

2. A 4 string LPS will not meet the MTTRes requirement of 4 hours if no spares and/or maintenance personnel are available at EDC to repair the failed string. If vendor maintenance is arranged, it must respond and repair the failed string within 3 hours (which is highly unlikely) to restore LPS operations.

3. A 5 string LPS can meet the operational availability (Ao) requirement of 0.96 and the MTTRes requirement of 4 hours provided that the fifth string is returned to LPS operations with minutes of issuing a request to the LPS test and development groups. This requires that the LPS fifth string, when returned, should be properly configured to replace the failed string and to support LPS operations. If a major reconfiguration of the fifth string is required, this may then jeopardize restoring of LPS operations within the required 4 hour of MTTRes time.

Table C.9-1a: Results of LPS RMA Analysis
(4 of 5 Strings to LPS Operations)

Operational Availability (Ao)	**0.9979058**					
MTTRes (minutes)	**55.00**					
RMA Modeling Calculations						
Down-Time Measurement Period (Hours):			10000			
or Total Time (Tt)						
Item Name	**Item MTBF**	**Items Required for Operations**	**Items Available to Operations**	**Downing Events over 10000 Hours**	**Switchover Time or Item MTTR (Minutes)**	**Average Down Time over 10000 Hours (Minutes)**
LPS String	1751	**4**	**5**	22.85	**55.00**	1256.54
Totals:				**22.85**		**1256.54**
RMA Calculation Assumptions:						
4 of 5 strings required for operation; restore LPS by switchover to the 5th. string.						
Orbit Period		90	Minutes			
Contact Period:		14	Minutes			
Available Time for Restore:		**76**	Minutes			
Time to Detect String Problem:		5	Minutes			
Time to Obtain String:		10	Minutes	**(from test/development)**		
Time to Bring-up LPS		15	Minutes			
Time to Test LPS		10	Minutes			
Time to Test w/ LGS/LP DAAC		15	Minutes			

Switchover/Restore Time:		**55**	Minutes			
Time to Wait for LS7 Pass:		**21**	Extra Minutes Available			

Table C.9-1b: Results of LPS RMA Analysis
(4 of 4 Strings to LPS Operations)

Operational Availability (Ao)	**0.9937173**					
MTTRes (minutes)	**165.00**					
RMA Modeling Calculations						
Down-Time Measurement Period (Hours):			10000			
or Total Time (Tt)						
Item Name	**Item MTBF**	**Items Required for Operations**	**Items Available to Operations**	**Downing Events over 10000 Hours**	**Switchover Time or Item MTTR (Minutes)**	**Average Down Time over 10000 Hours (Minutes)**
LPS String	1751	**4**	**4**	22.85	**165.00**	3769.61
Totals:				**22.85**		**3769.61**
RMA Calculation Assumptions:						
All 4 strings to operation; LPS restored by repairing failed string.						
Orbit Period		90	Minutes			
Contact Period:		14	Minutes			
Available Time for Restore:		**76**	Minutes			
Time to Detect String Problem:		5	Minutes			
Time to Repair failed String:		**120**	Minutes	**(Spares available on-site)**		

Time to Bring-up LPS	15	Minutes			
Time to Test LPS	10	Minutes			
Time to Test w/ LGS/LP DAAC	15	Minutes			
Switchover/Restore Time:	**165**	Minutes			
Time to Wait for LS7 Pass:	**-89**	**No time to capture next pass; two passes lost.**			

Table C.9-2: LPS Single String Configuration - RMA Calculations for Series Components

	(CM)			(1/SK)
Configuration / Component Name	**Component MTBF (CM)**	**K = (1/CM)**	**Sum of all Ks (SK)**	**Configuration MTBF**
LPS String			**0.00057115**	**1751**
Challenge L Power Board	310000	3.22581E-06		
CPU Board	35000	2.85714E-05		
Memory Board	35000	2.85714E-05		
16 MB SIMM 1	2400000	4.16667E-07		
16 MB SIMM 2	2400000	4.16667E-07		
16 MB SIMM 3	2400000	4.16667E-07		
16 MB SIMM 4	2400000	4.16667E-07		
16 MB SIMM 5	2400000	4.16667E-07		
16 MB SIMM 6	2400000	4.16667E-07		
16 MB SIMM 7	2400000	4.16667E-07		
16 MB SIMM 8	2400000	4.16667E-07		
POWERchannel I/O Board	35000	2.85714E-05		
S HIO Module	35000	2.85714E-05		
FDDI Board (VME)	35000	2.85714E-05		
Serial-to-Parallel Board	35000	2.85714E-05		
DSP Board	35000	2.85714E-05		
2GB Disk	500000	0.000002		
2GB DAT	40000	0.000025		
CD-ROM	250000	0.000004		
8 GB RAID Disk 1	500000	0.000002		
8 GB RAID Disk 2	500000	0.000002		
8 GB RAID Disk 3	500000	0.000002		
8 GB RAID Disk 4	500000	0.000002		
8 GB RAID Disk 5	500000	0.000002		
RAID Controller	40000	0.000025		
RAID SCSI Module	35000	2.85714E-05		
RAID Power Assembly	310000	3.22581E-06		

16 GB RAID Disk 1	500000	0.000002		
16 GB RAID Disk 2	500000	0.000002		
16 GB RAID Disk 3	500000	0.000002		
16 GB RAID Disk 4	500000	0.000002		
16 GB RAID Disk 5	500000	0.000002		
RAID Controller	40000	0.000025		
RAID SCSI Module	35000	2.85714E-05		
RAID Power Assembly	310000	3.22581E-06		
7.5 Mbps Recorder	10000	0.0001		
LPS Console/WS	10000	0.0001		

Appendix C.10 LPS Operational Cost Analysis

C.10.1 Objective

The objective of this analysis is to review the LPS operational costs which significantly affect the LPS life-cycle-costs (LCC). The following costs are considered:

a. LPS operations Costs

b. 60-day media refurbishment costs

c. LPS Hardware parts replenishment costs

C.10.2 LPS Operations

The LPS operations involves performing of the following key manual activities:

a. Review daily plan of activities and LGS schedules: 1.0 hour

b. Coordination with LGS, 6 times per day, start and end: 6 x 0.5 = 3.0 hours

c. Mounting, dismounting, and labeling of 60-day storage media: 6 x 0.5 - 3.0 hours

d. Review of Contact, Level 0R and transfer summaries: 6 x 0.5 = 3.0 hours

e. Attend to LPS alarms and alerts = 1.0 hour

f. Attend to LPS problems, if any: 1.0 hour

g. Shift turn-over / operations coordination: 1.0 hour

h. Making manual entries to operations log: 1.0 hour

Total: 14.0 hours (minimum)

It is recommended that a full-time operator should be assigned during each shift of LPS operations.

C.10.3 60- Media Refurbishment

The LPS design includes a digital linear tape (DLT) with an uncompressed capacity of 10 GB per cartridge. The DLT cartridge can be used as many as 3500 times before replacing it with a new one to maintain the BER performance of 10^{30}. A total of 24 tape cartridges are required to store data from all 4 LPS strings. Allowing some margin for tape quality problems and operational reserve, a total of 30 DLT cartridges will need to replaced a maximum of 4 times during the LPS life time.

C.10.4 Spare Parts

The LPS spares parts replenishment plan should be established in accordance with EDC guidelines and LPS availability requirements (0.96 with an MTTRes of 4 hours).

Appendix C.11 Reuse Analysis

The objective of this analysis is to identify and evaluate reusable hardware and software solutions and/or building blocks available within NASA and from NASA contractors. The following sections present the results of the reuse analysis, completed by the LPS Project, as of January, 1995. The LPS Project will continue to identify and evaluate such reusable alternatives throughout the system and subsystem design phases to reduce LPS implementation costs and risks, when possible. The results of all future reuse analysis will also be documented in this Appendix.

C.11.1 Hardware Reuse

a. <u>Science Data Receiver Board (SDRB) from Hughes Santa Barbara Research Center (SBRC)</u>

The Landsat Processing System (LPS) is required to perform non- real time frame synchronization on the 75 Mbps data received from the Landsat 7 satellite. Several options for accomplishing this function have been considered. One option that was considered, but not selected, was the SBRC Science Data Receiver Board (SDRB).

This board receives the 75 Mbps serial data, performs a rudimentary frame sync detection, PN decoding, CRC checking, and converts the 75 Mbps data to parallel for transfer through the Versa-Module European (VME) bus to additional cards.

The analysis of the frame synchronization circuit has revealed that the checking for the presence of a valid frame synchronization pattern is accomplished by shifting the data, one bit at a time, through a 32 bit shift register which feeds the A side of a 32 bit comparator with the 32 bit sync pattern hard wired to the B side input. A sync pulse is provided when there is a perfect match between the incoming 32 bit shifted pattern (A input) and the hard wired 32 bit (B input) desired sync pattern. Thus, anytime there is not a perfect match the frame is rejected and the data is lost. This method of detecting the sync pattern is sufficient for ground based testing where error rates are optimally low and the data isn't affected by the rigors of space to ground transmissions.

The LPS requires a more sophisticated algorithm to allow for the detection of near perfect frame sync patterns, bit slips, and frame length deviations. The SBRC unit, though well suited for Landsat Auxiliary Ground Equipment (AGE) purposes does not offer the flexibility required to handle data which is not always perfect.

Additionally, the capability to provide the same "comparator" style frame synchronization detection could be provided within the LPS front end for much less than the cost of the SBRC card.

b. <u>Application Specific Integrated Circuit (ASIC) technology developed by NASA Code 520</u>

The target system design for the LPS captures raw ETM+ wideband data directly to disk thereby removing the need for an expensive high speed tape device and permitting CCSDS processing in software in lieu of the traditional hardware.

The Application Specific Integrated Circuit (ASIC) technology developed by NASA offers a custom built hardware solution that provides Frame Synchronization and Reed Solomon bit correction at speeds up to 150 Mbps.

As of January 1995, prototyping results favor the development of CCSDS processing in software thereby eliminating the need to perform real-time frame synchronization with custom build hardware at the Sioux Fall South Dakota Facility. Furthermore a Custom Front End, designed specifically for the LPS, has life cycle issues such as hardware maintenance and technician training. Additionally the Reed Solomon algorithms must be modified to support bit error detection and correction on the frame header and a Bose-Chaudhuri-Hocquenghem (BCH) algorithm must be designed and implemented to perform bit error detection and correction on the mission data segment of each frame.

The cost issues of maintaining custom built hardware at a remote site and the necessary modifications to integrate the ASIC technology developed by NASA coupled with a raw ETM+ wideband data record requirement, no real-time Frame Synchronization requirement, and successful development of CCSDS processing prototypes in software drive the LPS architecture to one of little or no custom built hardware.

C.11.2 Software Reuse

As a result of the LPS system design, several areas for potential reuse of software code and/or design have been identified. The following indicate reuse areas which the LPS will continue to pursue. The list will be updated in subsequent design/development phases as other areas are identified.

<u>a. Prototypes:</u>

The LPS has implemented numerous prototypes during the requirements and system design phases. Each of these prototypes will be considered for reuse (either code and/or design) in the operational LPS system. These areas include: data capture, frame sync, CRC, PN decoding, and BCH error detection and correction.

<u>b. Renaissance Building Blocks/ Other IPD software development efforts:</u>

The LPS Data Transfer Subsystem (LDTS) has been designed to maximize the opportunity to reuse code from other development efforts. The LPS will continue to pursue code reuse in the data transfer and file management areas from either the Pacor II, Data Distribution Facility (DDF), or from Renaissance Building Blocks, which ever is most appropriate.

In addition, algorithms from past Landsat missions have been and will continue to be investigated for potential reuse. These include the WRS scene identification, the automatic cloud cover assessment, and the Sun azimuth and elevation angle determination algorithms.

c. LPS Items for Renaissance Building Blocks:

The LPS also has an opportunity to provide building blocks to the renaissance team. Some areas to consider for this have been discussed with the renaissance team. The LPS supplied building blocks may not conform to the renaissance standards because of the LPS performance considerations, but they will provide areas for others to reuse. Such areas include: frame sync in software, BCH, and others as identified.

Appendix C.12 LPS Risk Analysis

C.12.1 Objective

The objective of this analysis is to review the selected system design for the LPS and identify potential risks which, if encountered, may hinder the successful implementation of the LPS. This analysis also assesses the impacts of the LPS implementation risks and considers alternatives for mitigating them.

C.12.2 LPS Risks

The following table lists potential risks which may be encountered during LPS development. All risks may have impact on LPS costs and schedules.

Risk Identification	Probable Cause	Risk Mitigation
1. LPS unable to capture raw data at 75 Mbps to the disk array	raw data capture disk array and/or the DSP are unable to sustain a 75 Mbps data transfer throughput.	A prototype is being developed to benchmark this transfer throughput. **(Completed)**
2. LPS is unable to meet the 250 scenes per day production requirement.	SGI Challenge L unable to process data at the expected 7.5 Mbps rate	Upgrade SGI with more processors and/or the next higher performance model **(Completed)**
3. LPS is unable to meet accuracy requirement for WRS scenes.	Algorithm errors and complexity	Develop and benchmark early prototypes. Algorithm analysis and evaluation in progress.
4. LPS-LP DAAC interface is not baselined.	File segmentation and/or HDF formatting issues	Develop and benchmark file transfer prototypes.
5. Increase in LPS software size.	Increased complexity of PCD processing functions	Closely monitor PCD data processing software size during preliminary and detailed designs.

Appendix C.13 LPS Testability Analysis

C.13.1 Objective

The objective of this analysis is to review the system design selected for implementing the LPS and identify the various test data required during LPS integration and test activities. The test data identification approach analyzes dependencies of the LPS subsystems among themselves and considers potential sources for acquiring external test data. Special test data, if required for implementing the LPS system, is also identified. Table C.13-1 lists the test data items required by the LPS system.

Table B.13-1: LPS Test Data Requirements Analysis

LPS Subsystem	Input Test Data Required	Possible Input Test Data Sources /Reference	Output Test Data Available
Raw Data Capture Subsystem (RDCS)	Raw wideband data bit stream in NRZ-L format	Any wideband data bit stream NRZL source - Modified GTSIM (TBR)	Byte file on disk and tape
Raw Data Processing Subsystem (RDPS)	Raw wideband data with CCSDS Grade 3 and BCH data	- Modified GTSIM - Hughes/SBRC	Grade 3, BCH checked VCDUs

Major Frame Processing Subsystem (MFPS)	- Grade 3, BCH checked VCDUs - Test VCDUs with ETM+ minor frame/band patterns	- Modified GTSIM - LPS developers - Hughes/SBRC	LPS files: - Band files - Cal. file - MSCD file
Payload Correction Data Processing Subsystem (PCDS)	PCD segments (bytes)	- LPS developers	- PCD minor frames, major frame and cycle - PCD file

Table C.13-1: LPS Testability Analysis (contd.)

LPS Subsystem	**Input Test Data Required**	**Possible Input Test Data Sources /Reference**	**Output Test Data Available**
Image Data Processing Subsystem (IDPS)	- Band files - Test band files	- LPS MFPS test output band files - LPS developers.	LPS files: - Browse file - ACCA scores
Management and Control Subsystem (MACS)	-LPS Directives - LPS parameters - LPS test output files/results	- LPS developers.	LPS reports LPS Metadata file
Landsat Data Transfer Subsystem (LDTS)	- ASCII data test files - Data Availability Notices (DANs)	- LPS developers - LPS MFPS test output band files	LPS data output per LP DAAC ICD

C.14 HDF Evaluation

The Hierarchical Data Format (HDF) has been selected as the standard data format for all Earth Observing System (EOS) data products. Therefore, LPS will make Level 0R files available to the LP DAAC as HDF files. HDF files are normally created and accessed using the NCSA HDF package, consisting of a run-time library and command line utilities.

This study evaluates the suitability and impact of both the HDF file format and the HDF package on LPS processing. At the time of the study, details of the formats for LPS Level 0R files have been specified in only general terms. The study therefore confines itself to general features and limitations of HDF.

This report begins with a summary of the study's principal results. It continues with a more detailed description and evaluation of HDF that includes an overview, a summary of the standard data elements supported by HDF, an evaluation of the suitability of HDF standard data models for LPS Level 0R files, a summary of HDF programming limitations, and a summary of HDF file size overhead.

C.14.1 Summary

The HDF standard is sufficiently rich and flexible to accommodate LPS Level 0R files. However, HDF support for "Parameter=Value" style attributes for all data objects is available only in HDF 4.0, currently in alpha testing. Although LPS Level 0R file types can be accommodated using HDF standard data models, the actual format required by ECS and file size limitations (discussed below) may require the use of custom data models.

HDF data element size limitations may present problems for large LPS subintervals. HDF data elements may contain a maximum of 2 GBytes of raw data. Note however that a data element is a subset of the L0R data for a subinterval. For example, a single band would be a data element.

HDF file size is also limited to a maximum of 2 GBytes. However, because HDF supports external data objects, where the raw data is stored in a separate system file from the HDF descriptive headers, "virtual files" consisting of a top-level system file containing HDF descriptors and multiple system files each containing a 2 GByte maximum sized data element may be created. Using external data objects, the maximum file size is limited by the 2 GByte maximum size of the top-level descriptor file. In theory, it is possible to create an HDF file using external data objects containing over 21 million 2 GByte data elements. Using external data objects precludes the use of the HDF standard data models.

HDF overhead increases file size by a small amount. The increase is negligible for large data sets.

The HDF run-time library API restricts the implementation of LPS Level 0R file generators to C and FORTRAN In particular, implementing metadata file generation through Oracle stored procedures in PL/SQL does not seem to be viable.

HDF run-time libraries will add to the complexity of LPS software that creates output files. The degree of complexity will depend on both the complexity of the format required for LPS files and whether the required format uses HDF supported data models. NCSA HDF provides a relatively convenient interface to its supported data models. Custom models must use the NCSA HDF low-level I/O interface, which requires more DSI to create files. External data objects are supported only through the low-level I/O interface.

It is advisable for the LPS software development to acquire skill with the NCSA HDF package before implementation begins. While the HDF run-time library is relatively straightforward to use, there is a learning curve. This learning curve may become significant, if custom data models, data set hierarchies, and external data objects are used for LPS files. NCSA HDF 3.3 release 4 is available and apparently functional on SGI workstations; the package has been successfully built and used on the LPS Challenge server.

C.14.2 HDF Overview

Hierarchical Data Format (HDF) is both a standard file format and a package consisting of a run-time library and utilities that support the creation and manipulation of files in the standard format. HDF was developed and is maintained by the NCSA. The standard format is flexible, multi-object, machine-independent, and self-describing. HDF libraries provide a standard API (C and FORTRAN interfaces) across multiple platforms, insulating applications programs and users from the details of HDF file implementation. The HDF package is officially supported on a variety of platforms including Silicon Graphics/IRIX workstations and most other popular UNIX workstations, as well as Cray X-MPS2/UNICOS, VAX/VMS, PC/MS-DOS/Windows, and Macintosh/MacOS systems.

An HDF file is a collection of data elements. Each data element consists of the raw data plus data description information that identifies the data's type and location within the file. HDF includes the definition of a number of standard data element types. HDF also allows user-defined data element types. HDF allows the storage of external data elements, with an element's raw data stored outside of the HDF file. Data elements may be grouped into sets ("Vsets" and "Vgroups"). Since groups of data elements may also be members of groups, it is possible to create a hierarchy of groups with elements at leaf nodes.

HDF libraries and utilities support low-level and applications-level interfaces. The low-level interface provides the skilled programmer with direct access to HDF file I/O, error handling, and data element component manipulation functions. This style of access is possible for all standard data element types and is mandatory for user-defined data set types. The applications interface supports six standard data models (described below), built on the standard data elements.

The HDF package of run-time libraries and utilities is in the public domain and is available from NCSA's anonymous ftp site (ftp.ncsa.uiuc.edu). The current version is HDF 3.3 release 4. HDF 3.3r4 is installed on the LPS SGI Challenge server, l7serv, in ~dennisc/hdf. HDF 4.0 is currently in alpha testing. HDF 4.0 will provide support for N-bit scientific data sets (multidimensional arrays with elements that are integers of arbitrary bit width) and "Parameter=Value" style attributes for all objects.

C.14.3 HDF Standard Data Models

HDF libraries and utilities support the following six standard data models built on HDF standard data element types.

- 8-bit Raster – 8-bit raster images, their dimensions, and palettes; compression via run-length encoding, IMCOMP, or JPEG is supported for 8-bit rasters.
- Palette – 8-bit palettes storable outside the 8-bit Raster model.
- 24-bit Raster – 24-bit images and their dimensions; JPEG compression is supported for 24-bit rasters.
- Scientific Data Set (SDS) – multi-dimensional arrays of integer or floating-point numbers, their dimensions, number type, and attributes. Attributes include axis labels and scales, data point value ranges, calibration information, etc. The applications interface supports a set of standard attributes.
- Annotation – text strings describing a file or any of its data elements. The applications interface supports title and tag (long description) elements.
- Virtual Data (Vdata) – multi-variate data stored as records in a table. Vdata is analogous to a relation as defined in a relational database management system.

C.14.4 HDF Standard Data Models and LPS Level 0R File Types

Table C.14-1 indicates the suitability of the standard HDF data models for LPS data set types. Custom HDF data element types are an additional possibility for all data sets. Custom data element types will require additional software development to support their creation and access, not only in LPS but in other systems which access the data.

Table C.18-1 HDF Data Model Suitability for LPS Data Set Types

LPS Data Set	Raster-8	Raster-24	SDS	Annotation	VData
Band	•		•		
Multiband Browse	•	•	•		
PCD					•
MSCD					•
Cal/DC Rest					•
Metadata				•	•

"Parameter=Value" style attributes to be supported by HDF 4.0 represent another possibility for metadata storage.

The Raster-8 data model stores raster display images. This is obviously appropriate for Browse images. Multiband (Color) Browse images may be stored as three Raster-8 data sets. Level 0R image data might also be stored in this format, with one raster per band. A disadvantage of this data model is that the NCSA HDF applications level run-time library assumes a raster is written as a unit.

The Raster-24 data model stores color rasters (1 raster element = 3 8-bit color values). This is appropriate only for Color Browse files. As with the Raster-8 data model, the NCSA HDF applications level run-time library assumes a color raster is written as a unit.

Scientific data sets are a possible format for any data that can be modeled as a multidimensional array of elements of integer or real type. This certainly applies for LPS Band data, which can be viewed as a three dimensional array (band X scan row X sample). It is probably not appropriate for PCD, MSCD, or Calibration/DC Restore data. While these data types can be viewed as two-dimensional arrays of bytes with each frame representing a row, this data model will hide the fact that the bytes constitute fields within the frame. Also, time and status annotations cannot be conveniently attached to each frame.

VData is suitable for data sets that can be modeled as an array of records or a relational database style relation. This may be appropriate for PCD, MSCD, and Calibration/DC Restore data, which can be viewed as a repeating group of values (repeating once per frame). Time and status annotations are conveniently added as additional items in the group. Metadata files can also be modeled as VData, with the distinction that there is only one record in the data set.

C.14.5 HDF Programming Limitations

HDF is subject to limitations in several areas that may impact the way in which LPS-generated HDF files are defined. Table B.14-2 summarizes these limitations. HDF limitations arise both from manifest constant definitions ("#define") in HDF header files and from implementation limits, either hard coded in HDF libraries or defined in the standard file format. It is relatively straightforward to increase limits defined by a manifest constant. However, doing so may cause files created using the modified run-time library to be unusable with the standard HDF release. Hence, LPS data set users would need to make equivalent changes in their HDF run-time libraries. Also, the propagation of these modifications to each new HDF release represents a continuing maintenance task that increases overall life-cycle costs. Hard coded or file format based limitations are more difficult to overcome. Because HDF run-time library source is freely available, modifying the library itself is at least feasible. However, doing so probably represents a significant software development cost that, like the modification of manifest constants, is recurring for each HDF release and impacts LPS data set users.

C.14.6 HDF File Size Overhead

HDF introduces a relatively small amount of file size overhead. The format requires the following overhead items.

- A 4 byte identifier (magic number) at the start of each file.
- A 12 byte data descriptor for each data element in a file.
- One or more linked data variable length descriptor blocks containing a list of the data descriptors in the file. Each block can hold at most 65,535 data descriptors. Each block adds an additional 6 bytes of overhead.

In the case of the HDF supported data models, several data elements may be stored for a single data set. For example, a Raster-8 consists of two data elements – the raster itself and the raster's dimensions. Scientific data sets include an additional dimension specification.

Table C.14-2 HDF Limitations

Limits	Fixed	Value
Low-Level I/O		
Max. simultaneously open files		16
Max. simultaneously open access records		256
Total tags	•	32.767
Max. Length and Offset of File Element	•	2,147,483,647
Vgroup		
Max. Vset files open at a single time.		16
Max. Elements in a Vgroup	•	32,767
Max. Length of a Vgroup name or class		64
Max. vset files open at a single time		16
Max. characters in a single field name		128
Max. field order in a Vdata		32,000
Max. width of a Vdata record	•	32,767
Max. field width (bytes) of Vdata		MAX_FIELD_SIZE
RASTER IMAGES		
Max. width or height	•	2,147,483,647
Scientific Data Sets		
Max. dimensions per data set		MAX_VAR_DIMS
Max. dimension length	•	2,147,483,647
Max. attributes for a given object		MAX_NC_ATTRS
Max. data set name length		MAX_NC_NAME